MARS AND ITS CANALS

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MARS

AND ITS CANALS

BY

PERCIVAL LOWELL

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To

G. V. SCHIAPARELLI

THE COLUMBUS OF A NEW PLANETARY WORLD

THIS INVESTIGATION UPON IT

IS APPRECIATIVELY

INSCRIBED

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PREFACE

ELEVEN years have elapsed since the writer's first work on Mars was published in which were recorded the facts gleaned in his research up to that time and in which was set forth his theory of their explanation. Continued work in the interval has confirmed the conclusions there stated; sometimes in quite unexpected ways. Five times during that period Mars has approached the earth within suitable scanning distance and been subjected to careful and prolonged scrutiny. Familiarity with the subject, improved telescopic means, and long-continued training have all combined to increased efficiency in the procuring of data and to results which have been proportionate. A mass of new material has thus been collected, — some of it along old lines, some of it in lines that are themselves new, — and both have led to the same outcome. In addition to thus pushing inquiry into advanced portions of the subject, study has been spent in investigation of the reality of the phenomena upon which so much is based, and in testing every theory which has been suggested to

account for them. From diplopia to optical interference, each of these has been examined and found incompatible with the observations. The phenomena are all they have been stated to be, and more. Each step forward in observation has confirmed the genuineness of those that went before.

To set forth science in a popular, that is, in a generally understandable, form is as obligatory as to present it in a more technical manner. If men are to benefit by it, it must be expressed to their comprehension. To do this should be feasible for him who is master of his subject and is both the best test of, and the best training to, that post. Especially vital is it that the exposition should be done at first hand; for to describe what a man has himself discovered comes as near as possible to making a reader the co-discoverer of it. Not only are thus escaped the mistaken glosses of second-hand knowledge, but an aroma of actuality, which cannot be filtered through another mind without sensible evaporation, clings to the account of the pioneer. Nor is it so hard to make any well-grasped matter comprehensible to a man of good general intelligence as is commonly supposed. The whole object of science is to synthesize, and so simplify; and did we but know the uttermost of a subject we could make it singularly clear. Meanwhile technical phraseology,

useful as shorthand to the cult, becomes meaningless jargon to the uninitiate and is paraded most by the least profound. But worse still for their employ symbols tend to fictitious understanding. Formulæ are the anæsthetics of thought, not its stimulants; and to make any one think is far better worth while than cramming him with ill-considered, and therefore indigestible, learning.

Even to the technical student, a popular book, if well done, may yield most valuable results. For nothing in any branch of science is so little known as its articulation, — how the skeleton of it is put together, and what may be the mode of attachment of its muscles.

PERCIVAL LOWELL.

Oak Creek, Arizona,
June 1, 1906.

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PART I

NATURAL FEATURES

MARS AND ITS CANALS

CHAPTER I

ON EXPLORATION

FROM time immemorial travel and discovery have called with strange insistence to him who, wondering on the world, felt adventure in his veins. The leaving familiar sights and faces to push forth into the unknown has with magnetic force drawn the bold to great endeavor and fired the thought of those who stayed at home. Spur to enterprise since man first was, this spirit has urged him over the habitable globe. Linked in part to mere matter of support it led the more daring of the Aryans to quit the shade of their beech trees, reposeful as that umbrage may have been, and wander into Central Asia, so to perplex philologists into believing them to have originated there; it lured Columbus across the waste of waters and caused his son to have carved upon his tomb that ringing couplet of which the simple grandeur still stirs the blood: —

Á Castilla y á Leon
Nuevo mondo dió Colon;
(To Castile and Leon beyond the wave
Another world Columbus gave;)

it drove the early voyagers into the heart of the vast wilderness, there to endure all hardship so that they might come where their kind had never stood before; and now it points man to the pole.

Something of the selfsame spirit finds a farther field today outside the confines of our traversable earth. Science which has caused the world to shrink and dwindle has been no less busy bringing near what in the past seemed inaccessibly remote. Beyond our earth man's penetration has found it possible to pierce, and in its widening circle of research has latterly been made aware of another world of strange enticement across the depths of space. Planetary distances, not mundane ones, are here concerned, and the globe to be explored, though akin to, is yet very different from, our own. This other world is the planet Mars. Sundered from us by the ocean of ether, a fellow-member of our own community of matter there makes its circuit of the sun upon whose face features show which stamp it as cognate to that on which we live. In spite of the millions of miles of intervening matterless void, upon it markings can be made out that distantly resemble our earth's topography and grow increasingly suggestive as vision shapes them better; and yet among the seemingly familiar reveal aspects which are completely strange. But more than this: over the face of it sweep changes that show it to be

not a dead but a living world, like ours in this, and luring curiosity by details unknown here to further exploration of its unfamiliar ground.

To observe Mars is to embark upon this enterprise; not in body but in mind. Though parted by a gulf more impassable than any sea, the telescope lets us traverse what otherwise had been barred and lands us at last above the shores we went forth to seek. Real the journey is, though incorporeal in kind. Since the seeing strange sights is the essence of all far wanderings, it is as truly travel so the eye arrive as if the body kept it company. Indeed, sight is our only far viatic sense. Touch and taste both hang on contact, smell stands indebted to the near and even hearing waits on ponderable matter where sound soon dissipates away; only sight soars untrammeled of the grosser adjunct of the flesh to penetrate what were otherwise unfathomable space.

What the voyager thus finds himself envisaging shares by that very fact in the expansion of the sense that brought him there. No longer tied by means of transport to seas his sails may compass or lands his feet may tread, the traveler reaches a goal removed in kind from his own habitat. He proves to have adventured, not into unknown parts of a known world, but into one new to him in its entirety. In extent alone he surveys what dwarfs the explorer's conquests

on Earth. But size is the least of the surprises there in store for him. What confronts his gaze finds commonly no counterpart on Earth. His previous knowledge stands him in scant stead. For he faces what is so removed from every day experience that analogy no longer offers itself with safety as a guide. He must build up new conceptions from fresh data and slowly proceed to deduce the meaning they may contain. Science alone can help him to interpretation of what he finds, and above all must he wean himself from human prejudice and earthbound limitation. For he deals here with ultramundane things. With just enough of cosmogony in common to make decipherment not despairable this world is yet so different from the one he personally knows as to whet curiosity at every turn. He is permitted to perceive what piques inquiry and by patient adding of point to point promises at last a rational result.

Like mundane exploration, it is arduous too; *ad astra per aspera* is here literally true. For it is a journey not devoid of hardship and discomfort by the way. Its starting-point preludes as much. To get conditions proper for his work the explorer must forego the haunts of men and even those terrestrial spots found by them most habitable. Astronomy now demands bodily abstraction of its devotee. Its deities are gods that veil themselves amid man-crowded marts and

impose withdrawal and seclusion for the prosecution of their cult as much as any worshiped for other reason in more primeval times. To see into the beyond requires purity; in the medium now as formerly in the man. As little air as may be and that only of the best is obligatory to his enterprise, and the securing it makes him perforce a hermit from his kind. He must abandon cities and forego plains. Only in places raised above and aloof from men can he profitably pursue his search, places where nature never meant him to dwell and admonishes him of the fact by sundry hints of a more or less distressing character. To stand a mile and a half nearer the stars is not to stand immune.

Thus it comes about that today besides its temples erected in cities, monasteries in the wilds are being dedicated to astronomy as in the past to faith; monasteries made to commune with its spirit, as temples are to communicate the letter of its law. Pioneers in such profession, those already in existence are but the precursors of many yet to come as science shall more and more recognize their need. Advance in knowledge demands what they alone can give. Primitive, too, they must be as befits the still austere sincerity of a cult, in which the simplest structures are found to be the best.

Still the very wildness of the life their devotee is

forced to lead has in it a certain fittingness for his post in its primeval detachment from the too earthbound, in concept as in circumstance. Withdrawn from contact with his kind, he is by that much raised above human prejudice and limitation. To sally forth into the untrod wilderness in the cold and dark of a winter's small hours of the morning, with the snow feet deep upon the ground and the frosty stars for mute companionship, is almost to forget one's self a man for the solemn awe of one's surroundings. Fitting portal to communion with another world, it is through such avenue one enters on his quest where the common and familiar no longer jostle the unknown and the strange. Nor is the stillness of the stars invaded when some long unearthly howl, like the wail of a lost soul, breaks the slumber of the mesa forest, marking the prowling presence of a stray coyote. Gone as it came, it dies in the distance on the air that gave it birth; and the gloom of the pines swallows up one's vain peering after something palpable, their tops alone decipherable in dark silhouette against the sky. From amid surroundings that for their height and their intenancy fringe the absolute silence of space the observer must set forth who purposes to cross it to another planetary world.

But the isolation of his journey is not always so forbidding. His coming back is no less girt with grandeur

The Hermitage

of a different though equally detached a kind. Even before the stars begin to dim in warning to him to return, a faint suffusion as of half-suspected light creeps into the border of the eastern sky. Against it, along the far pine-clad horizon, mesa after mesa in shaggy lines of sentineling earth, stands forth dark marshaled in the gloom, informed with prescience of what is soon to come. Imperceptibly the pallor grows, blanching the face of night and one by one extinguishing the stars. Slowly then it takes on color, tingeing ever so faintly to a flush that swells and deepens as the minutes pass. One had said the sky lay dreaming of the sun in pale imagery at first that gathers force and feeling till the dreamer turns thus rosy red in slumbering supposition of reality. Then the blush dies out. The crimson fades to pink, the pink to ashes. The stars have disappeared and yet it is not day. It is the supreme moment of the dawn, the hush with which the Earth awaits its full awakening. For now again the color gathers in the east, not with the impalpable suffusion it had before but nearer and more vivid. No longer reflectively remote, rays imminent of the sun strike the upper air, the most adventurously refrangible turning the underside of a few stray clouds into flame-hued bars of glowing metal. They burn thus in the silent east first red, then orange, and then gold, each spectral tint in prismatic revelation coming to join the next till in a sudden

blinding burst of splendor the solar disk tops the horizon's rim.

Not less impressive is the journey when the afternoon watch has replaced the morning vigil by the drawing of the planet nearer to the sun. Lost in the brilliance of the dazzling sky, the planet lies hid from the senses' search. The quest were hopeless did not the mind guide the telescope to its goal. To theory alone is it visible still, and so to its predicted place the observer sets his circles, and punctual to the prophecy the planet swings into the field of view. One must be dulled by long routine to such mastery of mind not to have the act itself clothe with a sense of charmed withdrawal the object of his quest.

So much and more there are of traveler's glimpses by the way, compensation that offsets the frequent discomfort, and even balking of his purpose by inopportune cloud. For the best of places is not perfect, and a storm will sometimes rob him of a region he wished to see. He must learn to wait upon his opportunities and then no less to wait for mankind's acceptance of his results; for in common with most explorers he will encounter on his return that final penalty of penetration, the certainty at first of being disbelieved.

In such respect he will be even worse off than were the other world discoverers of the fifteenth and sixteenth centuries. For they at least could offer material proof

of things that they had seen. Dumb Indians and gold spoke more convincingly than the lips of the great navigators. To astronomy, too, that other world was due. Without a knowledge of the earth's shape and size got from Francisco of Pisa, Columbus had never adventured himself upon the deep. But more than this, an astronomer it was, in the person of Americus Vespucius, who first discovered the new world, by recognizing it as such; Columbus never dreaming he had lighted upon a world that was new. Nor does it impair one jot or tittle of his glory that he knew it not. Nothing can deprive him of the imperishable fame of launching forth into the void in hope of a beyond, though he found not what he sought but something stranger still.

So, curiously, has it been with the trans-etherian. To Schiaparelli the republic of science owes a new and vast domain. His genius first detected those strange new markings on the Martian disk which have proved the portal to all that has since been seen, and his courage in the face of universal condemnation led to exploration of them. He made there voyage after voyage, much as Columbus did on Earth, with even less of recognition from home. As with Columbus, too, the full import of his great discovery lay hid even to him and only by discoveries since is gradually resulting in recognition of another sentient world.

CHAPTER II

A DEPARTURE-POINT

AS the character of the travel is distinctive, so the outcome of the voyage is unique. If he choose his departure-point aright, the observer will be vouchsafed an experience without parallel on Earth. To select this setting-out station is the first step in the journey upon which everything depends. For it is essential to visual arrival that a departure-point be taken where definition is at its best. Now, so far as our present knowledge goes, the conditions most conducive to good seeing turn out to lie in one or other of the two great desert belts that girdle the globe. Many of us are unaware of the existence of such belts and yet they are among the most striking features of physical geography. Could we get off our globe and view it from without we should mark two sash-like bands of country, to the poleward side of either tropic, where the surface itself lay patently exposed. Unclothed of verdure themselves they would stand forth doubly clear by contrast. For elsewhere cloud would hide to a greater or less extent the actual configuration of the Earth's topography to an observer scanning it from space.

One of these sash-like belts of desert runs through southern California, Arizona, New Mexico, the Sahara, Arabia Petræa and the Desert of Gobi; the other traverses Peru, the South African veldt, and Western Australia. They are desert because in them rain is rare; and even clouds seldom form. In a twofold way they conduce to astronomic ends. Absence of rain makes primarily for clear skies and secondarily for steady air; and the one of these conditions is no less vital to sight than the other. Water vapor is a great upsetter of atmospheric equilibrium and commotion in the air the spoiler of definition. Thus from the cloudlessness of their skies man finds in them most chance of uninterrupted communion with the stars, while by suitably choosing his spot he here obtains as well that prime desideratum for planetary work, as near a heavenly equanimity in the air currents over his head as is practically possible.

From the fact that these regions are desert they are less frequented of man, and the observer is thus perforce isolated by the nature of the case, the regions best adapted to mankind being the least suited to astronomic observations. In addition to what nature has thus done in the matter, humanity has further differentiated the two classes of sights by processes of its own contriving. Not only is civilized man actively engaged in defacing such part of the Earth's surface as he comes in

contact with, he is equally busy blotting out his sky. In the latter uncommendable pursuit he has in the last quarter of a century made surprising progress. With a success only too undesirable his habitat has gradually become canopied by a welkin of his own fashioning, which has rendered it largely unfit for the more delicate kinds of astronomic work. Smoke from multiplying factories by rising into the air and forming the nucleus about which cloud collects has joined with electric lighting to help put out the stars. These concomitants of advancing civilization have succeeded above the dreams of the most earth-centred in shutting off sight of the beyond so that today few city-bred children have any conception of the glories of the heavens which made of the Chaldean shepherds astronomers in spite of themselves.

The old world and the new are alike affected by such obliteration. Long ago London took the lead with fogs proverbial wholly due to smoke, fine particles of solid matter in suspension making these points of condensation about which water vapor gathers to form cloud. With the increase of smoke-emitting chimneys over the world other centres of population have followed suit till today Europe and eastern North America vie with each other as to which sky shall be the most obliterate. Even when the obscuration is not patent to the layman it is evident to the meteorologist

or astronomer. By a certain dimming of the blue, smoke or dust reveals its presence high up aloft as telltalely as if the thing itself were visible. Some time since the writer had occasion to traverse Germany in summer from Göttingen to Cologne and in so doing was impressed by a cloudiness of the sky he felt sure had not existed when he knew it as a boy. For the change was too startling and extensive to be wholly laid to the score of the brighter remembrances of youth. On reaching Cologne he mentioned his suspicion to Klein, only to find his own inference corroborated; observations made twenty years ago being impracticable today. Two years later in Milan Celoria told the same story, the study of Mars having ceased to be possible there for like cause. Factory smoke and electric lights had combined to veil the planet at about the time Schiaparelli gave up his observations because of failing sight. With a certain poetic fitness the sky had itself been blotted just at the time the master's eye had dimmed.

America is not behind in this race for sky extinction. In the neighborhood of its great cities and spreading into the country round about the heavens have ceased to be favorable to research. Not till we pass beyond the Missouri do the stars shine out as they shone before the white man came.

Few astronomers even fully appreciate how much this means, so used does man get to slowly changing condi-

tions. It amounts, indeed, between Washington and Arizona to a whole magnitude in the stars which may be seen. At the Naval Observatory of the former sixty-four stars were mapped in a region where with a slightly smaller glass one hundred and seventy-two were charted at Flagstaff.

Besides their immediate use as observing stations these desert belts possess mediate interest on their own account in a branch of the very study their cloudlessness helps to promote, the branch here considered, the study of the planet Mars. They help explain what they permit to be visible. For in the physical history of the Earth's development they are among the latest phenomena and mark the beginning of that stage of world evolution into which Mars is already well advanced. They are symptomatic of the passing of a terraqueous globe into a purely terrestrial one. Desertism, the state into which every planetary body must eventually come and for which, therefore, it becomes necessary to coin a word, has there made its first appearance upon the Earth. Standing as it does for the approach of age in planetary existence, it may be likened to the first gray hairs in man. Or better still it corresponds to early autumnal frost in the passage of the seasons. For the beginning to age in a planet means not decrepitude in its inhabitants but the very maturing of this its fruit. Evolution of mind in its denizens continues

long after desolation in their habitat has set in. Indeed, advance in brain-power seriously develops only when material conditions cease to be bodily propitious and the loss of corporeal facilities renders its acquisition necessary to life.

The resemblance, distant but distinctive, of the climatic conditions necessary on earth for the best scanning of Mars with those which prove to be actually existent on that other world has a bearing on the subject worth considerable attention. It helps directly to an understanding and interpretation of the Martian state of things. Though partial only, the features and traits of our arid zones are sufficiently like what prevails on Mars to make them in some sort exponent of physical conditions and action there. Much that is hard of appreciation in a low, humid land shows itself an every-day possibility in a high and dry one. The terrible necessity of water to all forms of life, animal or vegetal, so that in the simple thought of the aborigines rain is the only god worth great propitiation upon the due observance of which everything depends, brings to one a deeper realization of what is really vital and what but accessory at best. One begins to conceive what must be the controlling principle of a world where water is only with difficulty to be had, and rain unknown.

But in addition to the fundamental importance of water, the relative irrelevancy of some other conditions

usually deemed indispensable to organic existence there find illustration too. On the high plateau of northern Arizona and on the still higher volcanic cones that rise from them as a base into now disintegrating peaks, the thin cold air proves no bar to life. To the fauna there air is a very secondary consideration to water, and because the latter is scarce in the lowlands and more abundant higher up, animals ascend after it, making their home at unusual elevations with no discomfort to themselves. Deer range to heights where the barometric pressure is but three fifths that of their generic habitat. Bear do the like, the brown bear of northern American sea-level being here met with two miles above it. Nor is either animal a depauperate form. Man himself contrives to live in comfort and propagate his kind where at first he finds it hard to breathe. Nor are these valiant exceptions; as Merriam has ably shown in his account of the San Francisco peak region for the Smithsonian Institution — a most interesting report, by the way — the other animals are equally adaptive to the zones of more northern latitudes on the American continent, zones paralleled in their flora and fauna by the zones of altitude up this peak. All which shows that paucity of air is nothing like the barrier to life we ordinarily suppose and is not for an instant to be compared with dearth of water. If in a comparatively short time an animal or plant

The San Francisco Peaks

accustomed to thirty inches of barometric pressure can contrive to subsist sensibly unchanged at eighteen, it would be rash to set limits to what time may not do. And this the more for another instructive fact discovered in this region by Merriam: that the existence of a species was determined not by the mean temperature of its habitat but by the maximum temperature during the time of procreation. A short warm season in summer alone decides whether the species shall survive and flourish; that it has afterward to hibernate for six months at a time does not in the least negative the result.

That the point of departure should thus prove of twofold importance, speeding the observer on his journey and furnishing him with a *vade mecum* on arrival, is as curious as opportune. Without such furtherance, to the bodily eye on the one hand and the mind's eye on the other, the voyage were less conclusive in advent and less satisfactory in attent.

CHAPTER III

A BIRD'S-EYE VIEW OF PAST MARTIAN DISCOVERY

WITH Mars discovery has from the start waited on apparent disk. To this end every optical advance has contributed from the time of Galileo's opera-glass to the present day. For apparent distance stands determined by the size of the eye. But although it is the telescopic eye that has increased, not the distance that has diminished, the effect has been kin to being carried nearer the planet and so to a scanning of its disk with constantly increasing particularity. Mankind has to all intents and purposes been journeying Marsward through the years. Any historic account of the planet, therefore, becomes a chronicle of seeming bodily approach.

Perhaps no vivider way of making this evident and at the same time no better preface to the present work could be devised than by putting before the eye in orderly succession the maps made of Mars by the leading areographers of their day, since the planet first began to be charted sixty-five years ago. The procedure is as much as possible like standing at the telescope and seeing the phenomena steadily disclose.

Seen thus in order the facts speak for themselves. They show that from first to last no doubt concerning what was seen existed in the minds of those competent to judge by systematic study of the planet at first hand, and furthermore, from their mutual corroboration, that this confidence was well placed. For, far from there being any conflict of authorities in the case, those entitled to an opinion in the matter prove singularly at one.

Beginning with Maedler in 1840 the gallery of such portraitures of the planet comprises those by Kaiser, Green and Schiaparelli, continued since Schiaparelli's time by the earlier ones of the present writer. To this list has been added one by Flammarion, which though not solely from his own work gives so just a representation of what was known at the date, 1876, as to merit inclusion. The remarkable drawings of Dawes and the excellent ones of Lockyer in 1862–1864 were never combined into maps by the observers, and though the former's were so synthesized by Proctor in 1867, the result was conformed to what Proctor thought ought to be and so is not really a transcript of the drawings themselves.

Each of the maps presented marked in its day the point areography had reached; and each tells its own story better than any amount of text. They are all made upon Mercator's projection and omit in

consequence the circumpolar regions. The later ones give, too, only so much of the surface as was shown at the opposition they record, for Mars, being tipped now one way, now another, regards the earth differently according to its orbital position. In comparing them, therefore, the equator must be taken for medial line. Mercator's projection has been the customary one for portraying Mars except for such oppositions as chiefly disclose the arctic pole. And this, too, with a certain poetic fitness. For it comes by right of priority to delineation of a new world; seeing that Mercator was the first to represent in a map the mundane new world in its entirety, by the rather important addition of North America to the southern continent already known, and to give the whole the title America with 'Ame' at the top of the map and 'rica' at the bottom.

In looking at the maps it is to be remembered that they are what we should call upside down, south standing at the top and north at the bottom. Inverted they show because this is the way the telescopic observer always sees the planet. The disk would seem unnatural to astronomers were it duly righted. Just the same do men in the southern hemisphere look at our own Earth topsy-turvy according to our view, the Sun being to the north of them and the cold to the south. Certain landmarks distinguishable in all the maps may serve for specific introduction. The V-shaped marking on the

equator pointing to the north is the Syrtis Major, the first marking ever made out upon the planet and drawn by the great Huyghens in 1659. The isolated oval patch in latitude 26° south is the Solis Lacus, the pupil of the eye of Mars; while the forked bay on the equator, discovered by Dawes, is the Sabaeus Sinus, the dividing tongue of which, the Fastigium Aryn, has been taken for the origin of longitudes on Mars.

Twelve maps go to make the series. They are as follows:—

	Maker	Date
I.	Map of Beer and Maedler	1840
II.	" " Kaiser	1864
III.	" " Flammarion (Résumé)	1876
IV.	" " Green	1877
V.	" " Schiaparelli	1877
VI.	" " "	1879
VII.	" " "	1881
VIII.	" " "	1884
IX.	" " Lowell	1894
X.	" " "	1896
XI.	" " "	1901
XII.	" " "	1905

If these maps be carefully compared they will be found quite remarkably confirmatory each of its predecessor. To no one will their inter-resemblance seem more salient than to draughtsmen themselves. For none know better how surprisingly, even when two

men have the same thing under their very noses to copy, their two versions will differ. Judgment of position and of relative size is one cause of variation; focusing of the attention on different details another. What slight discrepancies affect the maps are traceable to these two human imperfections. Maps IV and V make a case in point: it was to his new-found canals that Schiaparelli gave heed to the neglect of a due toning of his map; while Green, less keen-eyed but more artistic, missed the delicate canaliform detail to make a speaking portraiture of the whole.

Amid the remarkable continuity of progression here shown, in which each map will be seen to be at once a review and an advance, we may, nevertheless, distinguish three stages in the perception of the phenomena. Thus we may mark: —

I. A period of recognition of larger markings only; 1840–1877
II. A period of detection of canals intersecting the bright regions or lands; 1877–1892
III. A period of detection of canals traversing the 'seas' and of oases scattered over the surface; 1892–1905

Each period is here represented by four charts; and each expresses the result of a more minute and intimate acquaintance with the disk than was possible to the one that went before. To realize, however, how accurate

each was according to his lights it is only necessary to have the seeing grow steadily better some evening as one observes. He will find himself recapitulating in his own person the course taken by discovery for all those who went before, and in the lapse of an hour live through the observational experience of sixty years; in much the same way that the embryological growth of an individual repeats the development historically of the race.

Two verses of Ovid, which the poet puts into the mouth of Pythagoras, outline with something like prophetic utterance the special discoveries which mark the three periods apart. Ovid makes Pythagoras say of the then world:—

> Vidi ego, quod fuerat quondam solidissima tellus
> Esse fretum; vidi factas ex aequore terras;
> — OVID, *Metamorphoses* XV, 262.
>
> (Where once was solid ground I've seen a strait;
> Lands I've seen made from out the sea.)

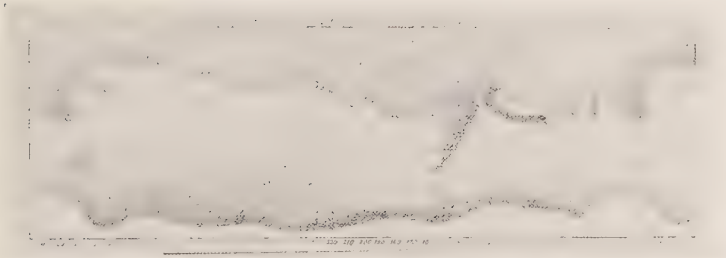
True as the verses are of Earth, the poet could not have penned them otherwise had he meant to record the course of astronomic detection on Mars. For they sound like a presentiment of the facts. A surface thought at first to be part land, part water; the land next seen to be seamed with straits; and lastly the sea made out to be land. Such is the history of the subject, and words could not have summed it more suc-

cinctly. "Vidi ego, quod fuerat quondam solidissima tellus esse fretum" rings like Schiaparelli's own announcement of the discovery of the 'canals.' Indeed, I venture to believe he would have made it had he chanced to recall the verse. So "vidi factas ex aequore terras" tells what has since been learned of the character of the seas.

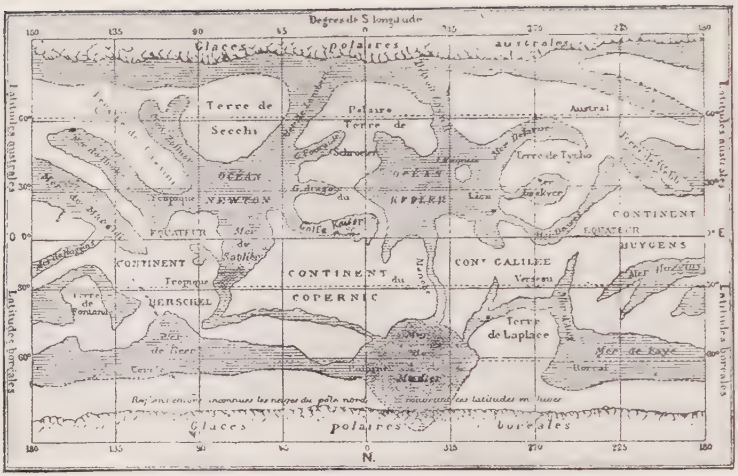
Of the three periods the first was that of the main or fundamental markings only. It came in with Beer and Maedler, the inaugurators of areography. That they planned and executed their survey with but a four-inch glass shows that there is always room for genius at the top of any profession and that instruments are not for everything in its instrumentality. Up to their day the reality of the planet's features had been questioned by some people in spite of having been certainly seen and drawn by Huyghens and others. Beer and Maedler's labors proved them permanent facts beyond the possibility of dispute.

The second period was the period of the discovery of the now famous canals, — a new era in the study of Mars opened by Schiaparelli in 1877 (Map V). Unsuspicious of what he was to stumble on, he seized the then favorable opposition to make, as he put it, a geodetic survey of the planet's surface. He hoped this undertaking feasible to the accuracy of micrometric measurement. His hopes did not belie him. He

Map I. Beer and Maedler, 1840.



Map II. Kaiser, 1864.
(From Flammarion's *Mars*.)



Map III. Résumé by Flammarion, 1876.
(From Flammarion's *Mars*.)

Map IV. Green, 1877.
(From Flammarion's *Mars*.)

found that it was possible to measure his positions with sufficient exactness to make a skeleton map on which to embody the markings in detail — and thus to give his map vertebrate support. But in the course of his work he became aware of hitherto unrecognized ligaments connecting the seas with one another. Instead of displaying a broad unity of face the bright areas appeared to be but groundwork for streaks. The streaks traversed them in all directions, tesselating the continents into a tilework of islands. Such mosaic was not only new, but the fashion of the thing was of a new order or kind. Straits, however, Schiaparelli considered them and gave them the name *canali*, or channels. How unfamiliar and seemingly impossible the new detail was is best evidenced by the prompt and unanimous disbelief with which it was met.

Unmoved by the universal scepticism which rewarded what was to prove an epoch-making discovery, Schiaparelli went on, in the judgment of his critics, from bad to worse — for in 1879 (Map VI) he took up again his scrutiny of the planet to the detecting of yet more particularity. He re-observed most of his old canals and discovered half as many more; and as his map shows he perceived an increased regularity in his lines.

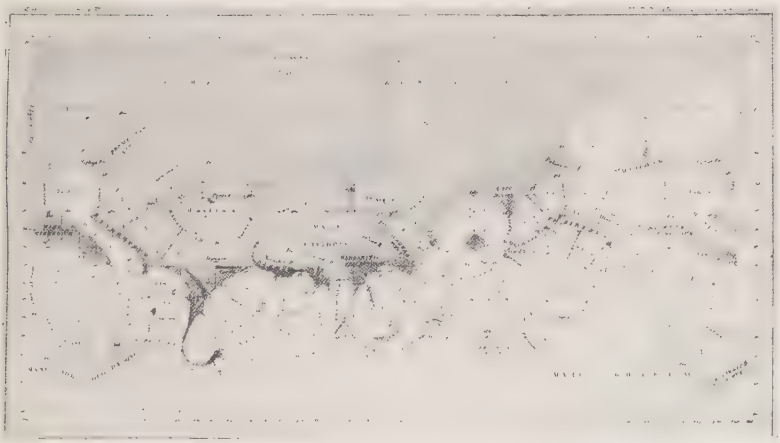
In 1881–1882 (Map VII) he attacked the planet again and with results yet further out of the common. His lines were still there with more beside. If they had

looked strange before, they now appeared positively unnatural. Not content with a regularity which seemed to the sceptics to preclude their being facts, he must needs see them now in duplicate. To the eyes of disbelief this was the crowning stroke of factitiousness.

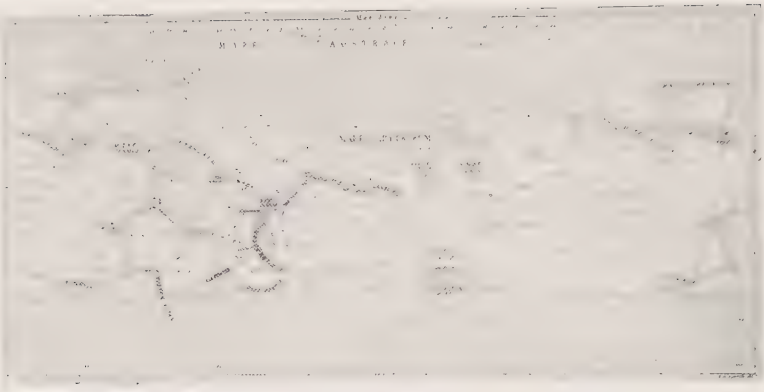
In consequence no end of adverse criticism was heaped upon his observations by those who could not see. But curiously enough, — what did not attract attention, — the blindness of the critics was as much mental as bodily. For they failed to perceive that the very unnaturalness which seemed to them to discredit his observations really proved their genuineness. His discoveries were so amazing that any change in strangeness simply went to confirm the universal scepticism and clouded logic. Yet properly viewed, a pregnant deduction stands forth quite clearly on a study of the maps.

On comparing maps V, VI and VII an eye duly directed is struck by a difference in the aspect of the lines. In his first map the 'canals' are depicted simply as narrow winding streaks, hardly even roughly regular and by no means such departures from the plausible as to lie without the communicatory pale. Indeed, to a modern reader prepared beforehand for geometric construction they will probably appear no 'canals' at all. Certainly the price of acceptance was not a large one to pay. But like that of the Sibylline

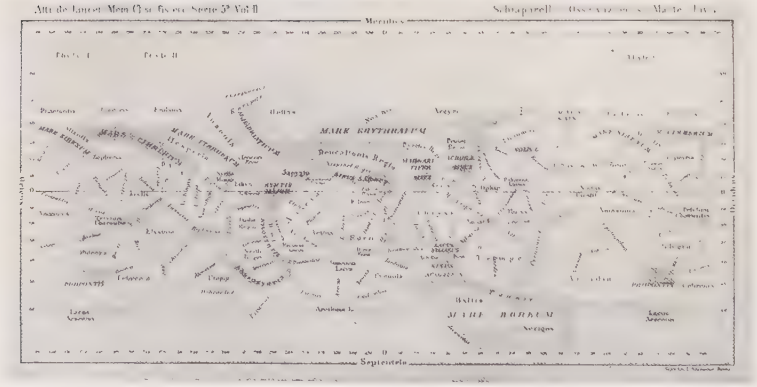
Map V. Schiaparelli, 1877.
(From Schiaparelli's *Memoria*.)



Map VI. Schiaparelli, 1879.
(From Schiaparelli's *Memoria*.)



Map VII. Schiaparelli, 1881.
(From Schiaparelli's *Memoria.*)

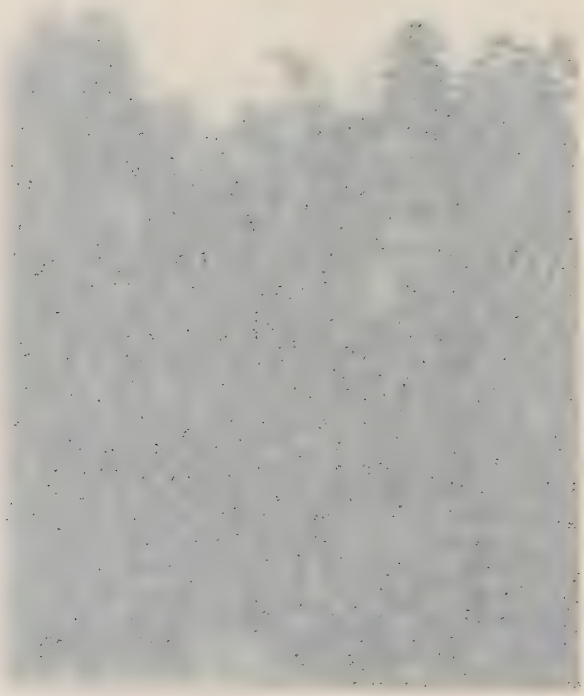


Map VIII. Schiaparelli, 1884.
(From Schiaparelli's *Memoria.*)

Mars' Hill

Books it increased with putting off. What he offered the public in 1879 was much more dearly to be bought. The lines were straighter, narrower, and in every way less natural than they had seemed two years before. In 1881–1882 they progressed still more in unaccountability. They had now become regular rule and compass lines, as straight, as even, and as precise as any draughtsman could wish and quite what astronomic facts did not desire. Having thus donned the character, they nevermore put it off.

Now, this curious evolution in depiction points, rightly viewed, to an absence of design. It shows that Schiaparelli started with no preconceived idea on the subject. On the contrary, it is clear that he shared to begin with the prevailing hesitancy to accept anything out of the ordinary. Nor did he overcome his reluctance except as by degrees he was compelled. For the canals did not change their characteristics from one opposition to another; the eye it was that learned to distinguish what it saw, and the brain made better report as it grew familiar with the messages sent it. In other words, it is patent from these successive maps that the geometrical character of the 'canals' was forced upon Schiaparelli by the things themselves, instead of being, as his critics took for granted, foisted on them by him. We have since seen the regularity of the canals so undeniably that we are not now in need



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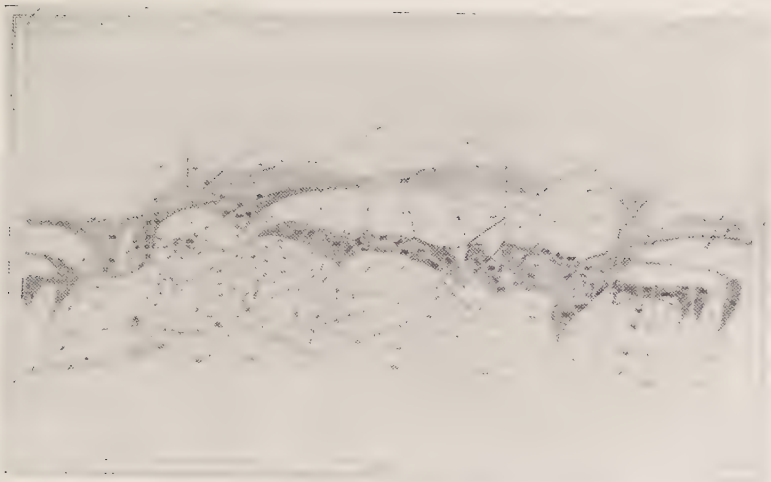
of such inferential support to help us to the truth; but too late, as it is, to be of controversial moment the deduction is none the less of some corroboratory force.

With the third period enters what has been done since Schiaparelli's time. For that master was obliged, from failing sight, to close his work with the opposition of 1890. In 1892 W. H. Pickering at Arequipa was the chief observer of the planet and made two important discoveries: one was the detection of small round spots scattered over the surface of the planet and connected with the canal system; the other the perception of what seemed to him more or less irregular lines traversing the Mare Erythraeum. Both were notable detections. The first set of phenomena he called lakes, the second river-systems, sometimes schematically 'canals,' but without committing himself to canaliform characteristics as his drawings make clear. The same phenomena were seen at that opposition at the Lick, by Schaeberle, Barnard and others, and called streaks. These discoveries took from some of the *maria* their supposed character. That there were no seas on Mars was discovered later at Flagstaff.

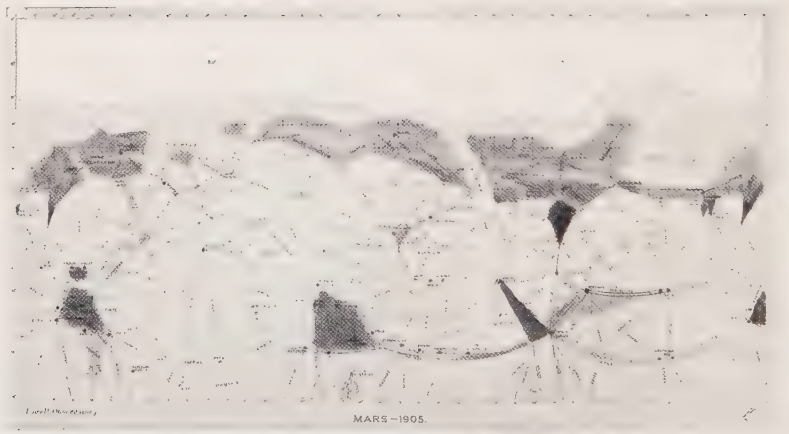
The next advance was the detection at Flagstaff in 1894 of their canaliform characteristics by my then assistant Mr. Douglass, who in place of the irregular streaks and river-systems of his predecessors found the seas to be crossed by lines as regular and



Map IX. Lowell, 1894.

Map X. Lowell, 1896.

Map XI. Lowell, 1901.



Map XII. Lowell, 1905.

as regularly connected as the canals in the light regions. To him they appeared broad and ill defined, but so habitually did to him the canals in the light areas, while for directness and uniformity the one set showed as geometrically perfect as the other. All the dark *maria* of the southern hemisphere he found to be laced with them and that they formed a network over the dark regions, counterparting that over the light. Still more significant was the fact that their points of departure coincided with the points of arrival of the bright-region canals, so that the two connected to form in its entirety a single system. After the publication of his results (Lowell Observatory Annals, Volume I, 1895) Schiaparelli identified some of those in the Syrtis with what he had himself seen there in 1888 (*Memoria*, VI, 1899), though his own had not been sufficiently well seen of him to impress him as canals.

Of other additions to our knowledge since made by the writer the present book treats; as also of the theory they originally suggested to him and which his later observations have only gone to confirm.

CHAPTER IV

THE POLAR CAPS

ALMOST as soon as magnification gives Mars a disk that disk shows markings, white spots crowning a globe spread with blue-green patches on an orange ground. The smallest telescope is capable of this far-off revelation; while with increased power the picture grows steadily more articulate and full. With a two and a quarter inch glass the writer saw them thirty-five years ago.

After the assurance that markings exist the next thing to arrest attention is that these markings move. The patches of color first made out by the observer are shortly found by him to have shifted in place upon the planet. And this not through mistake on his part but through method in the phenomena; for all do it alike. In orderly rotation the features make their appearance upon the body's righthand limb (in the telescopic image), travel across the central meridian of the disk and vanish over its lefthand border. One follows another, each rising, culminating and setting in its turn under the observer's gaze. A constantly progressing panorama passes majestically before his sight, new

objects replacing the old with a march so steady and withal so swift that a few minutes will suffice to mark unmistakably the fact of such procession. But for all this ceaseless turning under his gaze, after a certain lapse of time it is evident that the same features are being shown him over again. With such recognition of recurrence comes the first advance toward acquaintance with the Martian world. For that in all their journeying their configuration alters not, proves them permanent in place, part and parcel of the solid surface of that other globe. This surface, then, lies exposed to view and by its turning shows itself subject, like our earth, to the vicissitudes of day and night.

In such self-exposure Mars differs from all the four great planets, Jupiter, Saturn, Uranus and Neptune. Features, indeed, are apparent on the first two of these globes and dimly on the other two as well, but they lack the stability of the Martian markings. They are forever exchanging place. In the case of Jupiter what we see is undoubtedly a cloud-envelop through which occasional glimpses may possibly be caught of a chaotic nucleus below. With Saturn it is the same; and the evidence is that the like is true of Uranus and Neptune. What goes on under their great cloud canopies we can only surmise. With Mars, however, we are not left to imagination in the matter but so far as our means permit can actually observe what there takes place. Except for

distance, which, through science, year by year grows less, it is as if we hovered above the planet in a balloon, with its various features spread out to our gaze below.

Attention shows these areographic features to be on hand with punctual precision for their traverse of the disk once every twenty-four hours and thirty-seven minutes. For over two hundred years this has been the case, their untiring revolutions having been watched so well that we know the time they take to the nicety of a couple of hundredths of a second. We thus become possessed of a knowledge of the length of the Martian day and it is not a little interesting to find that it very closely counterparts in duration our own, being only one thirty-fifth the longer of the two. We also find from the course the markings pursue the axis about which they turn; and just as the period of the rotation tells us the length of the Martian day so the tilt of the axis, taken in connection with the form of the orbit, determines the character of the Martian seasons. Here again we confront a curious resemblance in the circumstances of the two planets, for the tilt of the equator to the plane of the orbit is with Mars almost precisely what it is for the Earth. The more carefully the two are measured the closer the similitude becomes. Sir William Herschel made the Martian 28°, Schiaparelli reduced this to 25°, and later determination by the writer

puts it nearer 24°. The latter is the one now adopted in the British Nautical Almanac for observers of the planet. This is a very close parallelism indeed; so that in general character the Martian seasons are nearly the counterpart of ours. In length, however, they differ; first because the year of Mars is almost double the length of the terrestrial one and secondly because from the greater ellipticity of Mars' orbit the seasons are more unequal than is the case with us, some being run through with great haste, others being lingered on a disproportionate time. It is usual on the Earth to consider spring as the period from the vernal equinox, about March 21, to the summer solstice, about June 20; summer as lasting thence to the autumnal equinox; autumn from this latter date, about September 20, to the winter solstice on December 21; and winter from that point on to the next spring equinox again. On this division our seasons in the northern hemisphere last respectively: spring, 93 days; summer, 94 days; autumn, 90 days; and winter, 89 days. On Mars these become, reckoned in our days: spring, 199 days; summer 183 days; autumn, 147 days; and winter, 158 days. If we had counted them in Martian days they would have totaled about one thirty-fifth less in number each.

In its days and seasons, then, Mars is wonderfully like the Earth; except for the length of the year we

should hardly know the difference in reckoning of time could we some morning wake up there instead of here. Only in one really unimportant respect should we feel strange; in months we should find ourselves turned topsy-turvy. But lunations have nothing to do with climate nor with the alternation between night and day; and in these two important respects we should certainly feel at home.

Though the axis could be determined by the daily march of any marking and thus the planet's tropic, temperate and polar regions marked out, the process is made easier by the presence of white patches covering the planet's poles and known, in consequence, as the polar caps. It is from measures of the patches that the position of the Martian poles has actually been determined. These polar caps are exactly analogous in general position to those which bonnet our own Earth. They reproduce the appearance of the ice and snow of our arctic and antarctic regions seen from space, in a very remarkable manner. In truth they are things of note in more ways than one and would claim precedence on many counts. Priority of recognition, however, alone entitles them to premier consideration. Among the very first of the disk's detail to be made out by man, they justly demand description first.

With peculiar propriety the polar caps have thus the *pas*. Not only do they stand first in order of

visibility, but they prove to occupy a like position logically when it comes to an explanation of the planet's present physical state. It is not matter of hazard that the most evident of all the planet's markings should also be the most fundamental, the fountain-head from which everything else flows. It is of the essence of the planet's condition and furnishes the key to its comprehension. The steps leading to this conclusion are as interesting as they are cogent. They start at the polar caps' visibility. For their size first riveted man's attention and then attention to them disclosed that most vital of the characteristics of the planet's surface: change.

Just as almost all of the features we note are permanent in place, showing that they belong to the surface, so are they all impermanent in character. Change is the only absolutely unchanging thing except position about the features the planet presents to view. It was in the aspect of the polar caps that this important fact first came to light. Not only did they thus initially instance a general law, they have turned out to make it; for by themselves changing they largely cause change in all the rest. But for a long time they alone exemplified its workings. To Sir William Herschel we owe the first study of their change in aspect. This eminent observer noted that their varying size was subject to a regular rhythmic wax and wane timed to

the course of the seasons of the planet's year. The caps increased in the winter of their hemisphere and decreased in its summer and being situate in opposite hemispheres they did this alternately with pendulum-like precision. His observations were soon abundantly confirmed, for the phenomena take place upon a vast scale and are thus easy of recognition. At their maximum spread the caps cover more than one hundred times as much ground as when they have shrunk to their minimum. In the depth of winter they stretch over much more than the polar zone, coming down to 60° and even 50° of latitude north or south as the case may be, thence melting till by midsummer they span only five or six degrees across.

In this they bear close analogue to the behavior of our own. Ours would show not otherwise were they viewed from the impersonal standpoint of space. Very little telescopic aid suffices to disclose the Martian polar phenomena in this their more salient characteristics and convince an observer of their likeness to those of the earth. Any one may note what is there going on by successive observations of the planet with a three-inch glass. Nor is the change by any means slow. A few days at the proper Martian season, or at most a couple of weeks, produces conspicuous and conclusive alterations in the size of these nightcaps of the planet's winter sleep. Resembling our own so well they were

early surmised to be of like constitution and composed, therefore, of ice and snow. Plausible on its face, this view of them was generally adopted and common sense has held to it ever since. It has encountered, of course, opposition, partly from very proper conservatism, but chiefly from that earth-centred philosophy which has doubted most advances since Galileo's time, and carbonic acid has been put forward by this school of sceptics to take its place. We shall critically examine both objections; the latter first, because a certain physical fact enables us to dispose of it at once. In casual appearance there is not much to choose between the rival candidates of common sense and uncommon subtlety, water and frozen carbonic acid gas, both being suitably white and both going and coming with the temperature. But, upon closer study, in one point of behavior the two substances act quite unlike, and had half the ingenuity been expended in testing the theory as in broaching it this fact had come to light to the suggestors as it did upon examination to the writer and had served as a touchstone in the case. At pressures of anything like one atmosphere or less carbonic acid passes at once from the solid to the gaseous state. Water, on the other hand, lingers in the intermediate stage of a liquid. Now, as the Martian cap melts it shows surrounded by a deep blue band which accompanies it in its retreat, shrinking to keep pace with the

shrinkage in the cap. This is clearly the product of the disintegration since it waits so studiously upon it. The substance composing the cap, then, does not pass instantaneously or anything like it from the solid to the gaseous condition.

This badge of blue ribbon about the melting cap, therefore, conclusively shows that carbonic acid is not what we see and leaves us with the only alternative we know of: water.

CHAPTER V

BEHAVIOR OF THE POLAR CAPS

ASSURED by physical properties that our visual appearances are quite capable of being what they seem we pass to the phenomena of the cap itself. Like as are the polar caps of the two planets at first regard, upon further study very notable differences soon disclose themselves between the earthly and the Martian ones; and these serve to give us our initial hint of a different state of things over there from that with which we are conversant on Earth.

To begin with, the limits between which they fluctuate are out of all proportion greater on Mars. It is not so much in their maxima that the ice-sheets of the two planets vary. Our own polar caps are much larger than we think; indeed, we live in them a good fraction of the time. Our winter snows are in truth nothing but part and parcel of the polar cap at that season. Now, in the northern hemisphere snow covers the ground at sea-level more or less continuously down to 50° of latitude. It stretches thus far even on the western flanks of the continents, while in the middle of them and on their eastern sides it extends ten degrees

farther yet during the depth of winter. So that we have a polar cap which is then ninety degrees across. In our southern hemisphere it is much the same six months later, in the corresponding winter of its year.

On Mars at their winter maxima the polar caps extend over a similar stretch of latitude. They do so, however, unequally. The southern one is considerably the larger. In 1903, 136 days after the winter solstice, in the Martian calendar February 27, it came down in longitude 225° to 44° of latitude and may be taken to have then measured ninety-three degrees across; in 1905, 121 days after the same solstice, it stretched in longitude 235° to latitude 42°, and 158 days later, in longitude 221° to latitude 41°; values which, supposing it to have been round, imply for it a diameter on these occasions of ninety-six and ninety-seven degrees. It was then February 20 and March 10 respectively of the Martian year. These determinations of its size at the two oppositions agree sufficiently well considering the great tilt away from us of the south pole at the time and the horizonward foreshortening of the edge of the snow. It seems from a consensus of the measures to have been some five degrees wider in 1903 than in 1905, which may mean a colder winter preceding the former date. The cap was still apparently without a dark contour in both years, showing that it had not yet begun to melt.

South Polar Cap.
(Lowell Observatory, 1905.)

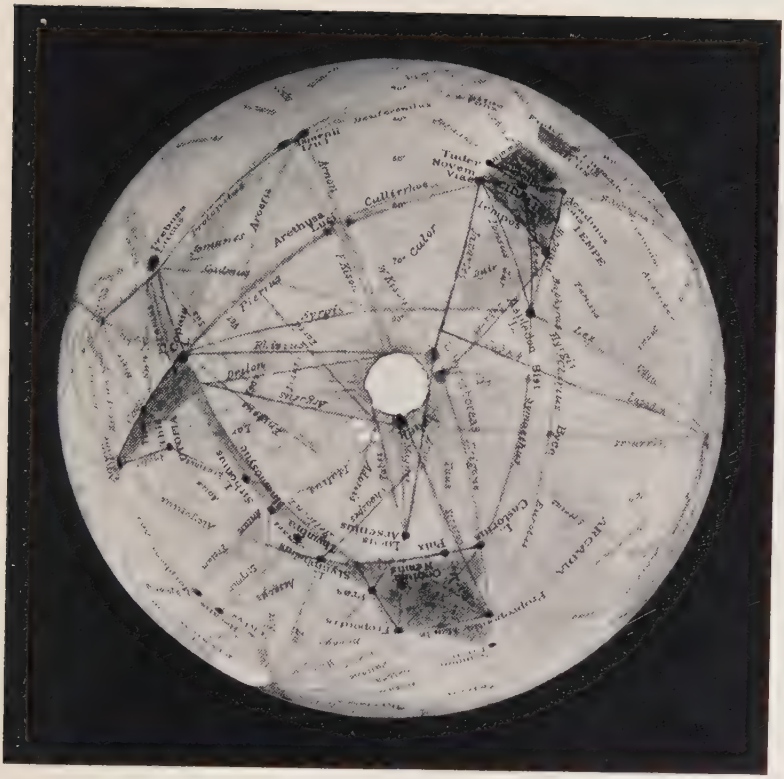
Less has been learnt of the northern cap. In 1896–1897 when it was similarly presented skirting the other rim of the disk, a gap occurred in the observations corresponding to the time by Martian months between February 24 and March 22. On the former date the cap came down only to latitude 55° in longitude 352°; on the subsequent one and for several days after the latitude of the southern limit of the snow was such as to imply a breadth to it of about eighty degrees. The cap was now bordered by a dark line, proving that melting had already set in. It cannot, however, at its maximum have covered much more country than this, in view of its lesser extent on February 24.

Fair as our knowledge now is of the dimensions of the Martian polar caps at their maxima, we have much more accurate information with regard to their minima, and this, too, was obtained much earlier. That we should first have known their smallest rather than their greatest extent with accuracy may appear surprising, exactly the opposite being our knowledge of our own. It is not, however, so surprising as it appears, inasmuch as it is an inevitable consequence of the planet's aspect with regard to the sun. When the tilt of the axis inclines one hemisphere toward the sun, that hemisphere's polar cap must melt and dwindle, while at the same time it is the one best seen, the other being turned away from the sun and therefore largely

from us as well; so that even such part of the latter as is illumined lies low down toward the horizon of the disk where a slight change of angle means a great difference in size.

It has thus come about that both the south and the north polar caps have been repeatedly well seen and measured at their minimum; and the measures for different Martian years agree well with one another. For the northern cap six degrees in diameter is about the least value to which it shrinks. The south one becomes even smaller, being usually not more than five degrees across, while in 1894 it actually vanished, a thing unprecedented. Its absence was detected by Douglass at Flagstaff and shortly after the announcement of its disappearance the fact was corroborated by Barnard at the Lick. The position the cap would have occupied was at the time better placed for observation in America than in Europe, inasmuch as the cap is eccentrically situated with regard to the geographic pole and its centre was then well on the side of the disk presented to us while in Europe it was turned away. This, together with the fact that it undoubtedly came and went more than once about this time, accounts for its disappearance not having been recognized there, haze left by it having apparently been mistaken for the cap itself.

On Earth the minima are much larger. In the



North Polar Cap.
(Lowell Observatory, 1905.)

northern hemisphere the line of perpetual snow or pack-ice in longitude 50° east runs about on the 80° parallel, including within it the southern end of Franz Joseph Land. Opposite this, in longitude 120° west, above the North American continent, it reaches down lower still to 75°. So that the cap is then from twenty to thirty degrees in diameter. In the southern hemisphere it is even larger. In longitude 170° west the land was found by Ross to be under perpetual snow in latitude 72°. Cook had reached in longitude 107° east an impassable barrier of ice in latitude 70° 23′. The season was then midsummer, January 30. So that we are perhaps justified in considering 71° south as about the average limit of perpetual snow or paleocrystic ice. This would make the southern cap at its minimum thirty-eight degrees across. Pack-ice with open spots extends still farther north. The Pagoda in 1845 was stopped by impenetrable pack-ice in south latitude 68° and the Challenger in 1874 encountered the pack in latitude 65° on the 19th of February, which corresponds about to our 19th of August, the time at which the sea should be most open. The limit of perpetual snow is thus lower in the southern than in the northern hemisphere. Here again, then, the two minima differ, but in the reverse way from what they do on Mars.

From this we perceive that the variations in size of

the caps are much more striking on Mars than on the Earth and that these are due chiefly to the difference in the minima, the maxima not varying greatly.

To explain these interesting diversities of behavior in the several polar caps we shall have to go back a little in general physics in order to get a proper take off. It is a curious concomitant of the law of gravity that the amount of heat received by a planet in passing from any point of its path to a point diametrically opposite is always the same no matter what be the eccentricity of the orbit. Thus, a planet has as many calories falling upon it in travelling from its vernal equinox to its autumnal as from the autumnal to the vernal again, although the time taken in the one journey be very different from that of the other. This is due to the fact that the angle swept over by the radius vector, that is, the imaginary bond between it and the sun, is at all points proportional to the amount of heat received; just as it is of the gravity undergone, the two forces radiating into space as the inverse square of the distance. Thus the heat received by a point or a hemisphere, through any orbital angle, is independent of the eccentricity of the orbit.

But it is not independent of the axial tilt. For the force of the sun's rays is modified by their obliquity. The amount of heat received at any point in consequence of the tilt turns upon the position of the point, and for

any hemisphere taken as a whole it depends upon the degree to which the pole is tilted to the source of heat. In consequence of being more squarely presented to its beams, the hemisphere which is directed toward the sun and therefore is passing through its summer season gets far more insolation than that which is at the same time in the depth of its winter. For a tilt of twenty-four degrees, the present received value for the axis of Mars, the two hemispheres so circumstanced get amounts of heat respectively in the proportion of sixty-three to thirty-seven.

But, though the summer and winter insolation thus differ, they are the same for each hemisphere in turn. Consequently the mere amount of heat received cannot be the cause of any differences detected between the respective maxima and minima of the two polar caps. If heat were a substance which could be stored up instead of being a mode of motion, the effect produced would be in accordance with the quantity applied and the two caps would behave alike. As it is the total amount has very little to say in the matter.

Not the amount of heat but the manner in which this heat is made at home is responsible for the difference we observe. Now, though the total amount is the same in passing from the vernal to the autumnal equinox as from the autumnal to the vernal, the time during which it is received in either case varies from one hemi-

sphere to the other. It is summer in the former while it is winter in the latter and the difference in the length of the two seasons due to the eccentricity of the orbit makes a vast difference in the result. Winter affects the maxima, summer the minima, attained. Of these opposite variations presented to us by the two caps, the maxima, the one most difficult to detect, is the easiest to explain, for the difference in the maxima seems to be due to the surpassing length of the antarctic night.

Owing to the eccentricity of the orbital ellipse pursued by Mars and to the present position of the planet's solstices, the southern hemisphere is farther away from the sun during its winter and is so for a longer time. The seasons are in length, for the northern hemisphere: spring, 199 days; summer, 183 days; autumn, 147 days; and winter, 158 days; while for the southern hemisphere they are: spring, 147 days; summer, 158 days; autumn, 199 days; and winter, 183 days. The arctic polar night is thus 305 of our days long; the antarctic, 382. Thus for 77 more days than happens to its fellow the southern pole never sees the sun. Now, since the total sunlight from equinox to equinox is the same in both hemispheres, its distribution by days must be different. In the southern hemisphere the same amount is crowded into a smaller compass in the proportion of 305 to 382; that being that hemisphere's

relative ratio of days. But since during winter the cap increases, there is a daily excess of accumulation over dissipation of snow and each twenty-four hours must on the average add its tithe to the sum total. Since the northern days are the warmer each adds less than do the southern ones; and furthermore there are fewer of them. On both these scores the amount of the deposition about the northern pole should be less than about the southern one. Consequently, the snow-sheet there should be the less extensive and show a relatively smaller maximum, which explains what we see.

With the minima the action is otherwise. Inasmuch as the greater heat received during the daylight hours by the southern hemisphere is exactly offset by the shortness of its season, it would seem at first as if there could be no difference in the total effect upon the two ice-caps.

But further consideration discloses a couple of factors which might, and possibly do, come in to qualify the action and account for the observed effect. One is that though the total amount of heat received is the same, the manner of its distribution differs in the two hemispheres. In the northern one the time from vernal to autumnal equinox is 382 days against 305 in the southern. Consequently, the average daily heat is then five fourths more intense in the southern hemi-

sphere. Indeed, it is even greater than this and nearer four thirds, because the melting occurs chiefly in the spring and in the first two months of summer when the contrast in length of season between the two hemispheres is at its greatest. Now, a few hotter days might well work more result than many colder ones. And this would be particularly true of Mars where the mean temperature is probably none too much above the freezing-point to start with. Ice consumes so much caloric in the process of turning into any other state, laying it by in the form of latent heat before it can turn into water and then so much more before this water can be converted into steam that a good deal has to be expended on it before getting any perceptible result. Once obtained, however, the heat is retained with like tenacity. So that the process works to double effect! If sufficient heat be received the ice is first melted, then evaporated and finally formed into a layer of humid air, the humidity of which keeps it warm. Dry air is unretentive of heat, moist air the opposite. And for the melting of the ice-cap to proceed most effectively the temperature that laps it about must be as high as possible and kept so as continuously as may be. If between days it be allowed to fall too low at night much caloric must needs be wasted in simply raising the ice again to the melting-point. This a blanket of warm air tends to prevent, and this again

is brought about by a few hot days rather than by many colder ones. It is not all the heat received that becomes effective but the surplus heat above a certain point. The gain in continuity of action thus brought about is somewhat like that exhibited between the running of an express and an accommodation train. To reach its destination in a given time the former requires far less power because it does not have to get up speed again after each arrest. Thus the whole effect in melting the snow would be greater upon that hemisphere whose summer happens to be the more intense.

The greater swing in size of the cap most exposed to the effects of the eccentricity is, then, the necessary result of circumstances when the precipitation is not too great to be nearly carried off by the subsequent dissipation. This is the state of things on Mars and the second of the factors above referred to. On the Earth as we have seen the polar caps are somewhat larger at their maximum and very much so at their minimum. Now, this is just what should happen were the precipitation increased. Suppose, for example, that the amount of precipitation were to increase while the amount of summer melting remained the same, and this would be the case if the vapor in the air augmented for one cause or another, and the result of each fresh deposit was locked up in snow. After a certain point the cap would grow in depth rather than

in extension; the winter deposit would be thicker but the summer evaporation would remain the same. Now, if this occurred, it is evident that the minimum size of the cap would increase relatively much faster than the maximum, and furthermore, that the relative increase of the minimum in the two caps would be greatest for that which had seasons of extremes. The result we see in the case of the Earth. In the arctic cap, where in consequence of the eccentricity of the orbit the winter is shorter, the maximum is less than in the antarctic and this extra amount of precipitation cannot be wholly done away with in its intenser summer, so that the minimum too is greater there.

We reach, then, this interesting conclusion. We find that eccentricity of orbit by itself not only causes no universal glaciation in the hemisphere which we should incidentally suppose likely to show it, but actually produces the opposite result, in more than offsetting by summer proximity what winter distance brings about. To cause extensive glaciation we must have, in addition to favorable eccentricity, a large precipitation. With these two factors combined we get an ice age, but not otherwise. The result has an important bearing on geologic glacial periods and their explanation.

Once formed, an ice-sheet cools everything about it and chills the climate of its hemisphere. It is a perpetual storehouse of cold. Mars has no such general

glaciation in either hemisphere, and the absence of it, which is due to lesser precipitation, together with the clearness of its skies, accounts for the warmth which the surface exhibits and which has been found so hard hitherto to interpret. Could our earth but get rid of its oceans, we too might have temperate regions stretching to the poles.

CHAPTER VI

MARTIAN POLAR EXPEDITIONS

POLAR expeditions exert an extreme attraction on certain minds, perhaps because they combine the maximum of hardship with the minimum of headway. Inconclusiveness certainly enables them to be constantly renewed, without loss either of purpose or prestige. The fact that the pole has never been trod by man constitutes the lodestone to such undertakings; and that it continues to defy him only whets his endeavor the more. Except for the demonstration of the polar drift-current conceived of and then verified by Nansen, very little has been added by them to our knowledge of the globe. Nor is there specific reason to suppose that what they might add would be particularly vital. Nothing out of the way is suspected of the pole beyond the simple fact of being so positioned. Yet for their patent inconclusion they continue to be sent in sublime superiority to failure.

Martian polar expeditions, as undertaken by the astronomer, are the antipodes of these pleasingly perilous excursions in three important regards, which if less appealing to the gallery commend themselves to the

philosopher. They involve comparatively little hardship; they have accomplished what they set out to do; and the knowledge they have gleaned has proved fundamental to an understanding of the present physical condition of the planet.

The antithesis in pole-pursuing between the two planets manifests itself at the threshold of the inquiry, in the relative feasibility with which the phenomena on Mars may be scanned. For, curiously enough, instead of being the pole and its surrounding paleocrystic ice which remains hidden on Mars, it is rather the extreme extent of its extension and the lowest latitudinal deposit of frost which lies shrouded in mystery. The difficulty there is not to see the pole but to see in winter the regions from which our own expeditions set out. And this because the poles are well displayed to us at times which are neither few nor very far between; while favorable occasions for marking the edge of the caps when at their greatest have neither proved so numerous nor so favorable. The tilt of the planet's axis when conveniently placed for human observation has been the cause of the one drawback; the planet's meteorological condition in those latitudes at that season the reason for the other.

What knowledge we have of the size of the caps in degrees upon the surface of the planet at this their extreme equatorward extension has been given in the

last chapter. Their aspect at the time together with what that aspect betokens was not there touched upon. With it, therefore, and the peculiarities it presents to view we shall begin our account of the caps' annual history.

When first the hemisphere, the pole of which has for half a Martian year been turned away from the sun, begins to emerge from its long hibernation, the snow-cap which covers it down even to temperate regions presents an undelimited expanse of white, the edges of which merge indistinguishably into the groundwork color of the regions round about. Of a dull opaque hue along its border, its contour is not sharp but fades off in a fleecy fringe without hard and fast line of demarcation. Such notably was the aspect of the north temperate zone in 1896 when, tilted as it then was away from us into a mere northern horizon of the planet's limb, it showed prior to the definite recognition of the north polar cap in August of that year, and such too was the look of the disk's southern edge both before and after the first certain detection of the southern cap in 1903 and 1905. Each was then in the depth of winter. For in Martian chronology the season cor-

South Polar Cap in winter.

responded in each at the time to what we know in our northern hemisphere as the latter part of February and the early part of March and the appearance of the planet's surface in both was not unlike what we know at the same season in latitude 45°. Indeed, there is reason to suppose bad weather there then and the extreme fringe, from the pale tint it exhibited, to have been cloud rather than snow.

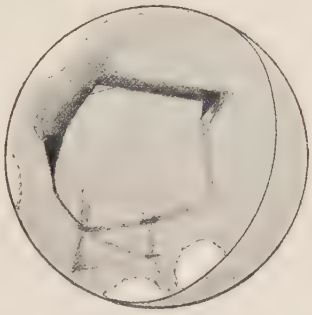
It is quite in keeping with what we know on earth or can conceive of elsewhere that such aspect should characterize the cap at or near the attainment of its greatest development. Whether it were not yet quite arrived at this turning-point of its career or had but slightly passed it a vagueness of outline would in either event proclaim the fact. For were the frost still depositing, the cap's edge would show indefinite; and on the other hand had it just begun to melt, evaporation would give it an undefined edge before the melting water had gathered in sufficient quantities to be itself noticeable.

Its behavior subsequent to recognition bore out the inference from its aspect when it first appeared. While for many days prior to its coming unmistakably into view it was impossible to say whether what was seen of the southern cap in 1903 and 1905 was cloud or snow; so even after it had definitely disclosed itself it continued to play at odds with the observer. Showing

sharp at the edges one day it would appear but hazily defined the next, thus clearly demonstrating itself to be at the then unstable acme of its spread. Such a state of things we are only too familiar with in our own March weather when after days of sunshine that have melted off the winter's white and fringed it with rivulets and awakening grass, a snow-storm falling upon it powders the ground again that was beginning to be bare and at one stroke extends the domain of the snow while mystifying the actual limits it may be said to occupy. The same condition of things, then, is not unknown on Mars, and to fix the precise date of so wavering a phenomenon is not so much matter of difficult observation as of physical impossibility.

Nor is the southern cap, at this the height of its winter expansion, confined strictly to its own proper limits. Faint extensions, now so connected with its main body as to form part and parcel of it, now so detached and dull of tint as to make the observer doubtful of the exact relationship, are generally to be seen attendant on it. Hellas in winter is much given to such questionable garb, and has in consequence been mistaken by more than one observer for the cap itself, appearing as it does well upon the southern limb and being often the only region to show white. Indeed, frost-bound as it then is, to consider it the polar cap, though possibly geographically incorrect, may cli-

matologically be sustainable. Its northern extremity extends down to latitude 30°, a pretty low latitude for frost. Still such equatorward extension is not without corroborating parallel. In 1903, at what was in Martian dates April 26, the whole of the region south of the Solis Lacus and the Nectar showed white, with a whiteness which may as well have been hoarfrost as cloud. Now, the Nectar runs east and west in latitude 28°. So that in this instance, too, it is possible that arctic conditions knocked at the very doors of the tropics. Encroachment of the sort is equivalent to snow in Cairo and permanent snow at that; not an occasional snow flurry, but something to linger on the ground and stay visible sixty millions of miles away.



Hellas in winter.

White south of Nectar and Solis Lacus.

Knowledge of either cap in this the midwinter of its year has been a matter of the most recent oppositions of the planet. Up to within the last few years our acquaintance with either cap was chiefly confined to the

months, — one might almost say the weeks, — immediately surrounding the summer solstice of its respective hemisphere. The behavior of the caps during the rest of their career was largely unknown to us, from the very disadvantageous positions they occupied at the times the planet was nearest to the earth. Beginning with 1894, however, our knowledge of both has been much extended, by a proportionate extension of the period covered by the observations. It used to be thought impracticable to observe the planet far on either side of opposition; now it is observed from as much as four months before that event to the same period after it. The result is a systematic series of observations which in many ways has given unexpected insight into Martian conditions. One of the benefits secured has been the lengthening of the period of study of the cap's career, a pushing of inquiry farther back into its spring history and a longer lingering with it in its autumnal rebuilding. Yet up to the very last opposition a gap in its chronology still remained between February 25 and April 1. The opposition of 1905 has bridged this hiatus and brought us down to the latter date, at which the melting of the cap begins in earnest.

From this point, April 1 on, we have abundant evidence of the cap's behavior. Its career now for some time is one long chronicle of contraction. Like Bal-

zac's *Peau de Chagrin* it simply shrinks, giving out of its virtue in the process. The cap proceeds to dwindle almost under the observer's eye till, from an enormous white counterpane spread over all the polar and a large part of the temperate zone, its area contracts to but the veriest nightcap of what it was before. From seventy degrees across it becomes sixty, then fifty, then forty, till by the middle of the Martian May it has become not more than thirty degrees in diameter. During this time, from the moment the melting began in good earnest, the retreating white is girdled by a dark band, of a blue tint, which keeps pace with the edge of the cap, shrinking as it shrinks, and diminishing in width as the volume of the melting decreases.

After the melting has been for some time under way and the cap has become permanently bordered by its dark blue band a peculiar phenomenon makes its appearance in the cap itself. This is its fission into one or more parts. The process begins by the appearance of dark rifts which, starting in from the cap's exterior, penetrate into its heart until at last they cleave it in two. Rifts have been seen by several observers and in both caps; and what is most suggestive they always appear in the same places, year after year. Sometimes oppositions elapse between their several detections for they are not the least difficult of detail; but when

they are caught, they prove to lie just where they did before.

The permanency in place of the rifts, a characteristic true of them all, shows them to be of local habit. Thus the rift of 1884 and 1897 reappeared again to another observer in the same position in 1901. They are, therefore, features of, or directly dependent on, the surface of the planet. But it will not do from this fact to infer that they are expressive of depressions there. The evidence is conclusive that great irregularities of surface do not exist on Mars. As we shall see when we come to consider the orology of the planet it is certain that elevations there of over two or three thousand feet in altitude are absent. Differences of temperature, able to explain a melting of the ice in one locality coincidentally with its retention in an adjacent one, must in consequence be unknown. And this much more conclusively than at first appears, for the reason that the smaller the planet's mass the less rapidly does its blanket of air thin out in ascent above the surface. This is in consequence of the greater pull the larger body exerts and the greater density it imparts to a compressible gas like our atmosphere. Gravity acts like any force producing pressure and by it the envelope of air is squeezed into a smaller compass. But as this is done throughout the atmospheric layer it means a more rapid rarefaction as one leaves the body. The

action is such that the height necessary to reach an analogic density varies inversely as the gravity of the mass. In consequence of this, to compass a relative thermometric fall for which a moderate difference of elevation would suffice on Earth, an immoderate one must be made on Mars. For gravity there being but three eighths what it is here, eight thirds the rise must be made to attain a proportionate lowering of temperature. This fact renders the above argument against elevation and depression being the cause of the phenomenon three times as cogent as it otherwise would be.

With so gradual a gradient in barometric pressure there and so low a set of contour lines, altitude must be a negligible factor in Martian surface meteorologic phenomena. Both density and temperature can be but little affected by such cause, and we must search elsewhere for explanation of what surface peculiarities we detect.

Meanwhile the rifts themselves, from being lines which penetrate the cap from its periphery in toward its centre, end by traversing it in its entirety and separating portions which, becoming outlying subsidiary patches, themselves proceed to dwindle and eventually disappear. The rifts usually take their rise from such broader parts of the cap-encircling blue belt as make beads upon that cordon and are clearly spots where the

product of the melting of the cap is either specially collected, or produces its most visible effect.

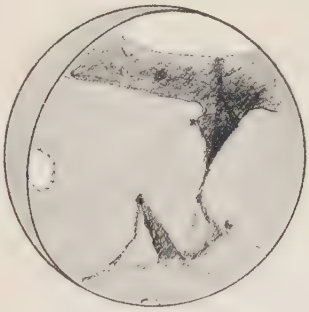
So far the description might apply with substantial accuracy to either cap. Yet the conduct of the two is in some ways diverse and begins to accentuate itself from this point on.

From the time that the north polar cap reaches a diameter of about twenty-five degrees, a singular change steals over it. From having been up to then of a well-defined outline it now proceeds to grow hazy and indistinct all along its edge. This change in its character at the same period of its career has been quite noticeable at each of the three last oppositions, so that small doubt remains that the metamorphosis is a regularly recurrent one in the history of the cap. Coincident with the obliteration of its contour, its dimensions seemingly enlarge. It is as if a hood had been drawn over the cap of a dull white different from the dazzling brilliance of the cap itself and covering more ground. Such is probably what occurs; with vapor for veil. The excessive melting of the cap produces an extensive evaporation which then in part condenses to be deposited afresh, in part re-

Northern Cap hooded with vapor.

mains as a covering, shutting off from our view the outlines of the cap itself. It would seem that at this time the cap melts faster than the air can carry it off. A sort of steaming appears to be going on, taking place *in situ*. For it clearly is not wafted away. The time of its coming too is significant. For the season is May 15, the height of time for a spring haze to set in. Then later it dissipates with the same quiet indefiniteness with which it gathered.

It is some time in Martian June before the spring haze clears away, and when it does go, only a tiny polar cap stands revealed beneath it, from six to eight degrees across, or from a tenth to a fifteenth of what it was when it passed into its curious spring chrysalis. The date of emergence varies. In 1903 it occurred early, the haze not being marked after June 3, though recurring again at intervals for a day or so. In 1905 it was later; perceptibly thin after June 21 it did not certainly clear away till June 9 and came back again on July 16 and possibly on the 25th.



Northern Cap unmasked.

These vicissitudes of aspect give us glimpses into a sweet unreasonableness in Martian weather which

makes it seem more akin to our own. And this on two counts, diurnal and annual. From day to day atmospheric conditions shift for purely local cause; while, furthermore, successive Martian years are not alike. In some the season is early; in others late. So that Mars is no more exempt than are we from the wantonness of weather.

Clearly disclosed thus reduced to its smallest possible terms it remains for some months of our days, for six weeks of its own. During that period it continues practically unchanged, neither increasing nor decreasing significantly in size, nor altering notably in aspect. Measures of the drawings of it then make it from five to eight degrees across and it is possible that it really fluctuates between narrow limits, though its clear-cut outline at all times renders the variation difficult to explain. We are not so near it as we could wish; for on these occasions even at their best it is over two hundred times as distant as the moon and the greatest magnification possible still leaves it a hundred thousand miles away.

To the south polar cap a somewhat similar history attaches, but with a difference. In its case no such regularly recurrent spring haze has yet been noted. The melting of this cap would seem to be of a more orderly nature than its fellow and not to outdo what can conveniently be carried off.

That an excess of evaporation should not take place is the more peculiar from the fact that at its maximum it is the larger of the two and therefore has the greater quantity of matter to get rid of. Its summer, also, is shorter than the arctic one, so that it has the less time to dispose of its accumulations. The only other respect in which it seems to be differently circumstanced from its antipodes is in the character of its surroundings. About it are large blue-green areas which with intermissions stretch down in places to within less than ten degrees of the equator; whereas the other pole is continuously encircled for long distances by practically uninterrupted ochre. The character of the environment seems thus the only thing that can account for the difference in behavior and this proves the more plausible when we come to consider what those two classes of regions respectively represent.

In other ways as well the southern cap is the more self-contained. The rifts, indeed, break it up into separate portions and these in part remain as outlying detachments of the main body, as was notably the case in 1877 and in 1894, but they hardly have the permanency and importance of those similarly formed about the arctic pole. Nothing antarctic for instance compares with the subsidiary patch of the north polar regions lying in longitude 206°, which both

in Schiaparelli's time, and during the late oppositions as well was almost as fixed a feature of the arctic zone as the cap proper. Not quite so constant, however, and not so solid-looking a landmark is this patch for all its extent, which nearly equals the area of the more legitimate portion. It bears on its face a more pallid complexion as if it were thinner, and this is borne out by the fact that it occasionally disappears, an event which so far at least has never befallen the northern cap itself.

Less constant the southern one is to its own minimum than the northern. In some seasons, in most in fact, it reaches like the other a more or less definite limit of diminution which it does not pass. But this is not always the case. In 1894 it disappeared entirely at the height of its midsummer. The season was probably unusually hot then in the southern hemisphere of Mars.

In position the caps have something to say about physiographic conditions. Both caps at their minima are then irregular and the centre of the south one is markedly eccentric to the areographic pole. It lies some six degrees north along the thirtieth meridian. The northern one is also probably eccentric, but much less so, with a divergence not much exceeding a degree and of doubtful orientation. Not only are both caps not upon their respective poles but they are not opposite each other, the one lying in longitude 30°, the other

in 290°. This speaks, of course, for local action. In some wise this must depend on the configuration of the surface, yet so far as markings go there is nothing to show what the dependence is.

The eccentring of the caps is paralleled by the like state of things on earth. The pole of cold does not coincide in either hemisphere with the geographic pole. On the earth its position is largely determined by the distribution of the land-masses. Continents are not such equalizers of heat as oceans because of their conductivity on the one hand and their immobility on the other. In winter they part with their heat more quickly and convection currents cannot supply the loss. This accounting for thermal pole eccentricity is inapplicable to Mars because of the absence there of bodies of water. And it is significant that the degree the earthly poles of cold are out much exceeds what is the case on Mars. Possibly areas of vegetation there replace to some effect areas of water. It is certainly in favor of this view that the arctic regions there are more desert than the antarctic and that the north pole of cold occupies more squarely the geographic pole.

Not till 1903 did the actual starting again of either cap chance to be seen. Nor was this, indeed, a matter of hazard but of persistent inquiry by observation prolonged after the planet had got so far away that its scanning had hitherto been discontinued. Such search

beyond the customary limits of observation was essential to success, because of the relation of the axial tilt to the position of the planet in its orbit. At an opposition well placed for nearness, the tilt is such as largely to hide the pole and to present the polar regions too obliquely to view for effective scanning. This is true both of the arctic and the antarctic regions in turn. For the Martian axis being inclined somewhat as our own is to the plane of the planet's orbit, we at times see well and at times but poorly the arctic or antarctic zones.

The cap, the starting to form of which was thus caught, was the arctic one; the date 128 days after the northern summer solstice, or thereabouts, for as is perhaps natural the advent of the phenomenon partook of the wavelike advance of such things familiar on earth, an advance succeeded by a recession and then followed by another advance. So much is proof of local weather there as here. Hoarfrost was successively deposited and then melted off.

Deposition of frost.

What is significant, the deposition of the frost took place simultaneously over large areas. The very first patch of it, in about longitude 320°, extended at one

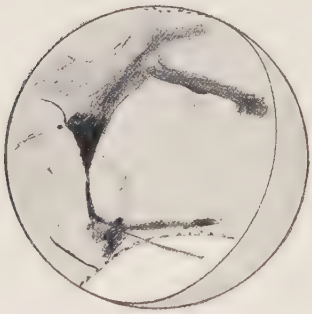
stroke down to latitude 55°. For it actually crossed the Pierius somewhat to the south. A second patch stretched to the east of the cap. Two wings these made to the kernel of cap itself. Through the wings could be marked the line of the canal: the Pierius upon the one side, the Enipeus upon the other. Such visibility of the canals through the white stretches proved the white not to be due to cloud suspended between us and them, but a surface deposit which found no lodgment upon the canals themselves. The same avoidance of dark markings was evidenced by the showing of the dark rim round the cap's kernel. Now, if the deposit were indeed hoarfrost, this failure to find permanent foothold on the dark markings is what we should expect to witness. For whether they were vegetation or water, equally in either case the frost would melt from them first. Probably they were both vegetal, though some doubt might exist about the latter, the band around the kernel. It was then August 20 in that hemisphere.

Such deposition over great stretches of country is perhaps not so surprising as it appears at first sight when seen from without in its totality. After all, something not unlike it occurs in our snow-storms when hundreds of square miles are whitened at once. Furthermore, with an atmosphere as thin as Mars seems to possess the temperature must be perilously near the

freezing-point in the arctic and subarctic regions at the close of summer.

Steadily, with intermissions, the white sheet increased until even the dark border to the cap became obliterate, the kernel showing at first through the veil like the ghost of what it had been, and then ceasing to be visible at all, its delimitations being buried under deeper and deeper depositions of frost.

The perennial portion of the cap was thus merged in the new-fallen snow. This marked the on-coming of the arctic winter in full force and happened even before the polar sun had wholly set. For the pole did not enter into the shadow till two of our months later, the autumnal equinox occurring 183 days after the summer solstice or 55 days after the first fall of frost. Then the pole passed into its star-strewn arctic night, a polar night of twice the duration of our own and the circumpolar regions entered upon their long hibernation of ten of our months.



First northern snow.

CHAPTER VII

WHITE SPOTS

IN addition to the polar caps proper and to the subsidiary polar patches that often in late summer flank them round about, other white spots may from time to time be seen upon the disk. In appearance these differ in no respect, so far as observed, from the arctic subsidiary snow-fields. Of the same pure argent, they sparkle on occasion in like manner with the sheen of ice. Equally with the polar caps they remain permanent in place during the period of their visibility and are themselves long-lived. Though by no means perpetual their duration is reckoned by weeks and even months, and they recur with more or less persistency at successive Martian years. That, when seen, they show in particular positions apparently unaffected by diurnal change precludes their being clouds, and this fact taken in connection with the character of their habitat is the puzzling point about them. For they affect chiefly the north tropic belt. They, or at least their nuclei, are small, about two or three degrees in diameter, and are not particularly easy of detection as a rule, though certain larger ones

are at times conspicuous. Chromatic, rather than formal, definition is necessary to their bringing out, as is witnessed by the superb colors the disk presents at the times when they are best seen. It is then that Mars puts on the look of a fire-opal.

The first such spot to be noticed was one which Schiaparelli detected in 1879, at the second opposition in which he studied the planet. He called it the Nix Olympica, showing that he recognized in it a cousinship to the polar snows. Yet it lay in latitude 20° north, longitude [1] 131°, in the midst of the ochre stretches of that part of the disk. It was a small roundish white speck of not more than two thirds the diameter of the polar cap. Reseen by him in 1881, it failed to appear at subsequent oppositions and was not caught again until 1888. Then once more it vanished, not to be detected anew till many years after at Flagstaff, coming out rather surprisingly in 1903. It showed, however, in the same place as before; so that its position but not its existence is permanent.

A similar but smaller patch was apparent to Schiaparelli at the same opposition of 1879. This one which

[1] Martian longitudes are now reckoned from the Fastigium Aryn, the mythologic cupola of the world, a spot easy of recognition because making the tongue in the jaws of the Sabaeus Sinus. It further commends itself because of lying within a degree of the equator. The longitudes are reckoned thence westward all the way round, or to 360°.

he styled the Nix Atlantica lay between the Thoth and the Syrtis Major. It was about half the size of the Nix Olympica and has never since been seen, though it should have been had it continued to be what it then was.

On the other hand, phenomena of the sort undetected of Schiaparelli have been remarked at Flagstaff. On May 18, 1901, I was suddenly struck by the singular whiteness of the southeast corner of Elysium where that region bordered the Trivium. Elysium has a way of being bright but not with such startling intensity as this spot presented nor in so restricted an area as was here the case. The spot was so much whiter than anything I had ever previously seen outside the polar caps that it arrested my attention at once. And this the more that I had observed this same part of the planet the day before and perceived nothing out of the ordinary. Once detected, however, the spot continued visible. The next day it was there with equal conspicuousness, and now thrust an arm across the Cerberus, entirely obliterating the canal for the space of several degrees. In this salience it remained day after day till the

White in Elysium.

region passed from sight, to reappear with it six weeks later when the region again rounded into view. The hour of the Martian day seemed to make no difference in its visibility. It was seen from early morning till Martian afternoon, as late as the phase permitted. Clearly there was nothing diurnal about its revealing, and it lasted for at least three months and a half, until the planet got so far away that observations were discontinued.

It was to all appearances and intents snow. But now comes the singular fact about it. It lay within ten degrees of the equator and showed from the end of June to the latter part of August. To our ideas there could be no more inopportune place or time for such an exhibition. For it cannot have been due to a snow-capped peak, as we know for certain that there are no mountains in this, or in any other, part of the planet. Besides, it had not appeared in previous Martian years; which it infallibly would have done had it been a peak. Indeed, it baffles explanation beyond any Martian phenomenon known to me. It seems directly to contradict every other detail presented by the disk.

The phenomenon is thus unique in kind; it is not, however, unique as a specimen of its kind. The eastern coast of Aeria where that region borders the Syrtis Major is prone to a brilliance of the same sort. It is

a narrow belt of country that shows thus, nothing but the coastline itself, but this for a considerable distance stretching several hundred miles in length. It has stood out saliently bright now at every opposition which I have observed, beginning with 1894. Sometimes it has been described in the notes as bright simply, sometimes as white, and once, in 1901, as glistening at one point like ice. Yet when upon the terminator it has never stood forth as a mountain range should have done to declare its character.

It has been evident regardless apparently of the Martian season. In 1894 it was bright from October 25 to January 16 (Martian chronology); in 1896, from December 22 to January 7; in 1901, from July 13 to the 15th; in 1903, at about the same date and so in 1905. It was whitest during the latter oppositions, showing that the effect is most marked in its midsummer. All of the above instances of extra-polar white have been located within the tropics. Examples of the same thing, however, occur in the north temperate zone. Tempe, a region just to the west of the Mare Acidalium, is exceedingly given to showing a small white spot close upon the Mare's border in latitude 50° north. This spot, too, on occasion glitters as it were with ice. It is also at times very small. So that whereas much of Tempe is by nature bright but a small kernel of it is dazzling.

The list might be easily extended from the record book. Thus on March 1 and 2, 1903, the disk showed speckled with minute white spots, one in Arcadia in latitude 41° north, one in Tharsis near the equator, a third just north of the Phoenix Lucus in 10° south, and a fourth, the Nix Olympica, and on April 11, a glittering pin-point starred like a diamond the centre of the Pons Hectoris. On both these occasions the Martian season was summer; July 9 for the latter, June 21 for the former date.

White in the Pons Hectoris.

As one approaches the north pole spots of like character become more numerous. Especially are such visible north of the Mare Acidalium in the arctic region thereabout, from 63° to 75° north.

From so widespread a set of instances the only explanation which seems to fit the phenomena is that the mean temperature of Mars is low, not very much above freezing, and that whatever causes a local fall in the temperature results in hoar-frost. Such an explanation accords well with the distance of the planet from the sun and the thinness of its atmosphere. At the same time it shows that the mean temperature over the greater part of the planet the greater part of the time

is above the freezing-point and that consequently it is no bar to vegetation of a suitable sort.

That the hoar-frost should be found even at the equator may perhaps be due to the very thinness of the air-covering of Mars, which would tend to make the actual insolation more of a factor than it is with us, and by the great length of the Martian seasons. In midsummer the greatest insolation occurs in the arctic and temperate, not in the tropic regions; on the other hand, an atmosphere tends to accumulate heat for the tropics. With us the latter factor is prepotent; it would be less effective on Mars. Then again the double duration of summer would tend to emphasize insolation as the important factor in the matter. But it is possible that greater deposition plays a part in the matter. On earth the rainfall is greatest near the equator and something of the sort may be true of the zones of moisture on Mars. That the most striking spots are found to the west of large dark areas may in this connection have a meaning inasmuch as, such regions being vegetation-covered, the air over them is probably more moisture-laden.

One point about the position of the spots is of moment: they have all been found in the northern hemisphere or within ten degrees of it in the southern equatorial region. This seems at first a question of hemispheres; but when we consider that the light areas

of the surface are chiefly in the boreal hemisphere and in the south tropic belt, we perceive that it may be rather the character of the surface there than the particular hemisphere in the abstract that is decisive in the matter. Nevertheless, the austral hemisphere is the hemisphere of extremes, possessing a shorter, hotter summer and a longer, colder winter than its antipodes. This would not favor sporadic small depositions of frost in summer so much as would a climate of a more mean temperature.

From the relative lack of atmospheric covering over the planet we should expect the nights to prove decidedly cool, while the days were fairly warm. Of this we have perhaps evidence in a singular aspect shown by the Mare Acidalium in June, 1903. The account of it in the Annals reads thus: "On May 22 an interesting and curious phenomenon presented itself. On that day, so soon as the Mare Acidalium had well rounded the terminator on to the disk, at λ352°, the whole of its central part showed white, the edges of the marking alone remaining as a shell to this brilliant core. So striking was the effect that beside appearing in the drawing it found echo in the notes. The next day no mention is made of it, and a drawing made under λ20° shows the Mare as usual and the bright spot in Tempe in its customary place. Neither was anything of the sort noticed on the 24th and 25th.

But on the 26th, the day of the projection (upon the terminator), the effect of the 23d reappeared, the longitude of the centre being 332°. Fortunately on that day a further drawing was secured which enabled its subsequent behavior to be followed. Made three hours later than the other, the longitude of the centre being 13°, this drawing shows the Mare well on the disk, its whole area as dark as usual and with Tempe bright to the right of it toward the terminator. The terminator in question was the sunrise one, and we are offered two suppositions in explanation of the phenomenon: either the white was due to a morning deposition of hoar-frost which dissipated as the sun got up, or obliquity rendered some superficial deposit visible which more vertical vision hid. That the former inference is the more probable seems hinted at by the simultaneous appearance from the 19th to the 26th of other areas of white between the Mare and the pole. May 26 was 88 days after the northern summer solstice, and corresponded to July 31 on the earth." Annals, Volume III, § 564.

In this connection mention may pertinently be made of Schiaparelli's repeated observation of regions that whiten with obliquity, a proclivity to which he particularly noticed Hellas and certain 'islands' in the Mare Erythraeum to be prone. Here as with the Mare Acidalium we certainly seem to be envisaging cases of matutinal frost melted by midday under the sun's rays.

CHAPTER VIII

CLIMATE AND WEATHER

IN gazing at the successive phases presented by the polar caps as their annual history unrolls itself to view, beginning with vast white cloaks that in winter hide so effectively the planet's shoulders, to little round knobs that in summer sit like guardsmen's caps more or less askew upon the poles, the bodily eye sees only the glisten of far-off snow. The mind's eye, however, perceives something more: the conviction they carry of the presence of an atmosphere surrounding the planet. Elusive as water vapor is to sight for its transparency and to spectroscopic determination for its earthly omnipresence, recognition of its existence elsewhere by deduction raises such reasoning at once to a more conspicuous plane than it might otherwise assume. Especially is this true where the deduction is itself conclusive, as is here the case. For it depends on phenomena not its own, but which are in their turn dependent on it. We are not even beholden to any knowledge of the substance composing the caps for the fundamental inference that an atmosphere surrounds them. Whatever that substance were, the fact that

the caps dissipate and reform shows us with absolute certainty that they pass into the gaseous state, to be later solidified afresh. This gas constitutes of itself an atmosphere; while another phenomenon, to wit, their blue girdles as they melt, affirming their substance to be snow and ice, enables us to precise the fact that this gas is water vapor.

From such premise given us by the polar caps we are able to infer much more by the help of the kinetic theory of gases. But the speed of parting by a planet with its gases is conditioned by the mean speed of each gas. Water vapor will, therefore, go before nitrogen, oxygen or carbonic acid gas. If, then, we find it present over the surface of a planet we are assured of the possibility that the other three may be there too, and from the similarity of matter in space strong reason to suspect that they actually are.

Corroborative evidence of the accuracy of the deduction as to the presence of a Martian air is shown in several other ways; in the existence of clouds to begin with. Rare as they are, these certainly float at times over parts of the planet, although it is doubtful whether they can then be seen. Fortunately for assurance we have other ways of ascertaining their presence than that of obscuration. Nor is it of account to the argument that they should be few and far between, as they

unquestionably are. One single instance of such mediumistic support is enough to support the theory of a medium; and that instance has been more than once observed.

Direct evidence of atmosphere is further forthcoming in the limb-light. This phenomenon might be described as a brilliant obscuration. It is a circlet of illumination that swamps the features as they near the full edge of the disk, the limb of the planet as it is called. Obliteration of the sort is evident, more or less markedly, at all times, and is not due to foreshortening, as the broadest areas are affected. The fading out of the detail at the limb suggests nothing so much as a veil drawn between us and it, lighter in tint than what it covers. Such a veil can be none other than air or the haze and cloud that air supports. From its effect, impartial in place and partial in character, cloud is inadmissible as a cause and we are left with air charged with dust or vapor in explanation. Obscuration due to it should prove most dense at the limb, since there the eye has to penetrate a greater depth of it; just as on the earth our own air gives azure dimness to the distance in deepened tinting as the mountains lie remote.

Another bit of evidence lies in the apparent detection of a twilight arc. In 1894 measures made of the polar and equatorial diameters of the planet showed

certain systematic residuals left after all known corrections had been applied. The only thing which would account for them was the supposition that a twilight arc had been unconsciously seen and as unconsciously measured. In delicate quantities of the sort too great reliance cannot be put, but if the residuals be not referable to other cause they give us not only further evidence of an atmosphere, but at the same time our only hint of that atmosphere's extent. From them it would seem that the air must be rare, not more than about four inches of barometric pressure, as we reckon it, and probably less; a thin, high air more rarefied than prevails upon our highest mountain tops.

Corroborative of this is the aspect of the planet. From the general look of the disk a scant covering of air is inferable. For one of the striking things about the planet's features is their patent exposure to our sight. Except in the winter time of its hemisphere or in the spring after the greatest melting of the polar cap, nothing seems to stand in our way of an uninterrupted view of the surface, whether in the arctic, temperate, or tropic zones. From the openness of its expression, however, too much case should not be made as we really know but little of how an atmosphere-enshrouded planet would look. We find no difficulty in seeing objects a hundred miles away across the surface of the earth and yet the thickness of the air strata

in such horizontal traversing is many fold what it is when we look directly up. It is also out of all proportion laden with dust and smoke. In the purer regions of the earth, a clear air imposes but little bar to sight, and conjures up far things startlingly distinct.

Nevertheless, every evidence points to a thin air upon Mars: *a priori* reasoning, indirect deduction and direct sight. Now, from a thinness of atmosphere it would follow, other things equal, that the climate was cold. About this there has been much question, but less of answering reply. From the distance of the planet from the sun it is certain less heat is received by it than falls upon the earth in something like the ratio of one to two. But that the amount effective is as the amount received is far from sure. The available heat is much affected by the manner of its reception. A blanket of air acts like the glass of a conservatory, letting the light rays in, but hindering the heat rays out. The light rays falling on the ground or the air are transformed into heat rays that, finding the return journey less easy, are consequently trapped. All substances are thus calorifiers, but water vapor is many times more potent than ordinary air to heat-ensnaring. A humid air has a hothouse tang to it most perceptible. Now, what the relative percentage of water vapor in the Martian atmosphere may be we do not know.

The thinness of the Martian air has caused it to be likened to that upon our highest mountain peaks which are in large part covered with perpetual snow. But the comparison is not well founded. A peak differs materially from a plateau in the countenance it gives to the heat falling upon it. On a plateau each warmed acre of ground helps the retention of heat by its neighbor; while in addition to being destitute of side support the higher winds generated about an isolated peak blow its own caloric away. Still less does any analogy hold between the two when the plateau is a world-wide one.

From these considerations it is evident glosses are possible upon the bald idea of a much lower temperature prevailing on the Martian surface than on the earth's. Doubtless the theoretic cold has been greatly overdone. Reversely, recent observations tend to lower the apparent temperature disclosed by the features of the disk, and between the rising of the theoretic and the falling of the observed we are left with a very reasonable compromise and reconcilement as the result.

The various look and behavior of the surface of Mars point to a mean temperature colder than that of the earth, but above the freezing-point of water; for regions, at least, outside of the polar caps and during all but the winter months. Except at certain special spots, and possibly even there, frost is unknown at all times within the tropics and except in winter in tem-

perate latitudes. These anomalous localities, mentioned in the preceding chapter, may be said to be the exceptions that prove the rule of general non-glaciation. For if they be snow, they stand witness to its absence elsewhere upon the disk, and if they are not, they testify the more emphatically to the same effect.

As between different parts of the surface, the tilt of the Martian axis and the greater length of the Martian seasons, the one the same as, the other the double of, our own, tend to an accentuation of the heat in the temperate and arctic or antarctic zones. The greatest insolation on earth is not, as we might suppose, at the equator, but at the parallels of 43.°5 north and south; even the poles themselves receiving a quarter as much heat again on midsummer day as ever falls to the lot of the line. This broad physical fact is equally true of Mars, while in the matter of consecutive exposure Mars in summer outdoes the earth. For the longer the seasons, the more nearly does the effective heat approach the received amount. Thus both on the score of heat received and of heat husbanded these zones must be relatively warm. And this shows itself in the look of the surface. In summer it is clearly warmer within the polar regions than is the case on earth, to judge by the effect. In winter the cold is doubtless proportionately severe.

For the diurnal range of temperature we have less

data. There is evidence pointing to chilly nights, but it is meagre, and we are left to fall back on the cold of our deserts at night for analogic condition of the state of things over the Martian desert levels after the sun goes down.

If we are uncertain of the precise character of the Martian climate, we know on the other hand a good deal about the Martian weather. A pleasing absence of it over much of the planet distinguishes Martian conditions from our own. That we can scan the surface as we do without practical interruption day in and day out proves the weather over it to be permanently fair. In fact a clear sky, except in winter, and in many places even then, is not only the rule, but the rule almost without exceptions. In the early days of Martian study cases of obscuration were recorded from time to time by observers, in which portions of the disk were changed or hidden as if clouds were veiling them from view. More modern observations fail to support this deduction, partly by absence of instances, partly by other explanation of the facts. Certainly the recorded instances are very rare. Indeed, occasions of the sort must to any Martians be events, since only one possible example has presented itself to me during the course of my observations, extending more or less over eleven years. Even in this case there was no obliteration, though a certain whiteness overspread an area near

the equator temporarily. Position seemed to point to its identity with a cloud which made its appearance about that time upon the terminator, and lasted for some thirty-six hours. The cloud, however, showed evidence of being, not the kind with which we are familiar, but a dust-storm, in keeping, indeed, with the desert region (Chryse) in which it originated.

With the exception of sporadic disturbance of the sort the whole surface of the planet outside the immediate vicinity of the polar caps seems free from cloud or mist and to lie perpetually unveiled to space. In the neighborhood of the caps, however, and especially round about their edge, a very distinct pearly appearance is presented during the months at which the cap is at its maximum, or in other words, in the depth of its winter. Of a dull white hue and indefinite contour the phenomenon suggests cloud. Where it lies spread no markings are visible; an absence explicable by obscuration due an interposed medium, but equally well by seasonal non-existence of the markings themselves, which from the general behavior of these markings we know to be to some extent certainly the fact. Of the regions where the effect is noticeable, Hellas is the most striking. So conspicuously white during the winter of the southern hemisphere as to have been often mistaken for the polar cap, its ghost shows thus almost regularly every Martian year. What is as suggestive as it is striking,

the blanching is confined to the solid circle constituting Hellas and does not extend into the dark regions by which it is circumscribed. Hellas is as self-contained when thus powdered as when, in its normal ochre or abnormal red, it stretches like a broad buckler across the body of the disk. That the land there lies at a higher level than its surroundings is pretty certain, but that the difference can amount to enough to explain its silveriness as ice is improbable. In latitude Hellas is distinctly temperate, lying between the parallels of 55° and 30°; but on Mars this is no warrant of a like climate. Again, though close on the south to what constitutes the polar cap, it does not strictly form part of that cap, but occupies both in position and in kind a something intermediary between the frost-bound regions of periodic snow and the warmer ones of perpetual sunshine. It seems to be afflicted with the winter weather of the north of Europe, and to owe its pearly look at such times to the same cloud canopy that then distressingly covers those inclement lands.

Similar in behavior to it is the long chain of so-called islands that, beginning southwest of Thaumasia, runs thence westward even to the eastern edge of Hellas. These belt the planet in a west-northwesterly direction by a strip of territory from ten to fifteen degrees wide, the medial line of which begins at 55° south and ends in about 40°. They are parted from

the main bright areas by blue-green 'seas' of about the same width as themselves, the Mare Sirenum, the Mare Cimmerium and Mare Tyrrhenum. These 'seas' the white that covers the 'islands' never crosses; though the continent, as we may call it for convenience, descends at the east to 30° south. Since the 'seas' are not seas, the cause which might bound the snow, were they such, cannot be the cause here. Nevertheless, they have an effect of some sort on the isothermal lines as is shown not only by latitudinal comparison with the state of things in Hellas, but with that in Thaumasia as well. For 30° south is also the limit apparently of the white on Thaumasia, where ochre desert stretches ten degrees farther south still; the region in its southern part being white-mantled, in its northern part not. Here again, then, the ochre areas make exception to what affects the blue-green ones. Clearly the blue-green regions temper the action of what gives them wintry cloak. But why they should do this is not easy to explain on any supposition terrestrial or marine. Bodies of water tend to foster the formation of clouds; so, less markedly, do areas of vegetation. Neither the old ideas, then, nor the new lend themselves in explanation. It may be that while we here seem to be envisaging cloud we are in reality looking at hoarfrost. On the other hand, light cloud would show less, superposed over a dark background, than over an ochre

one; and this, the simplest of all explanations, may be the true one. It is facts like these that intrigue us in the study of the Martian surface by revealing conditions which render offhand analogy with the earth unsafe. Indeed, we are more sure of some things which appear too strange to be true than of others so simple on their face as to enlist belief. Among the most difficult and perplexing are meteorological problems like the above. Here we can only say provisionally that while cloud best answers to the appearance, frost best fits the cause. For vegetation might melt frost, yet not dissipate cloud. By raising our conception of the mean temperature the facts can, however, be reconciled and this is probably the solution of the difficulty after all.

As we saw in the annual history of the polar caps a dimness somewhat different affects the northern cap in May and June. After the melting of the cap is well under way a haziness sets in along its edge which befuddles its outline and effectually hides what is going on within it. When at last the screen clears away the cap is found to be reduced to its least dimensions. Such obstructing sheet looks to be more of the nature of mist caused by the excessive melting of the cap. Unfortunately, there are here no patches of blue-green to test a possible partiality in its behavior over such tracts; nor has similar action ever yet been remarked in the case of the cap of the southern hemisphere.

Regular recurrence at the appropriate season of the planet's year, together with extensive action at the time, takes this springtide mist to some extent out of the domain of weather into that of climate. For it prevails all round the cap and repeats itself in place as each fresh spring comes on. At least it has done so for the past three oppositions at which it has been possible to observe well the arctic zones. It is thus both general in its application and fixed in its behavior. Nevertheless, it betrays something of the fickleness which characterizes that more inconstant thing: weather. For it comes and goes, one thinks for good, only to find it there again some days later. Not less captious is the meteorologic action shown in the making of the new polar cap. When the northern one starts to form, vast areas of frost are deposited in a single night. These, however, are not permanent. The ground thus covered is during the next few days again partially laid bare. Then a new fall occurs, hiding the surface a little more completely than before, and the lost domain is more than regained. By such wave-like advance and recession the tide of frost creeps over and submerges the arctic regions as the late summer passes into the autumn. In this alternate coming and going with succeeding days, we have an unsteadfastness of action most fittingly paralleled by our own weather. It would seem that local causes there as here

are superposed upon the orderly progress of the seasons and though at the on-coming of the autumn the cold is steadily gathering strength, nevertheless warm days occur now and then to stay its hand, only to be succeeded in their turn by frosts more biting than before. Even on Mars nothing in the way of weather is absolutely predicable but impredicability.

CHAPTER IX

MOUNTAINS AND CLOUD

IN all ways but one our scrutiny of the planet is confined to such view as we might get of it from the car of a balloon poised above it in space; from which disadvantage-point we should see the surface only as a map spread out below us, a matter of but two dimensions. The exception consists in the observation of what are called projections; irregularities visible when the disk is gibbous upon that edge of the planet where the light fades off. Striking phenomena in themselves they are of particular value for what may be deduced from them. For by them we are afforded our only opportunity of gaining knowledge of the surface other than in plan and thus of determining between peak, plateau, or plain that to a bird's-eye view alike lie flattened out to one dead level.

It might at first be thought that our best chance of noting any elevations or depressions of the Martian surface lay in catching that surface in profile, by scanning the bright edge of it which stands sharp-cut against the sky and is called the limb. For this is practically what we do on earth when we mark a

mountain against the horizon and measure its height by triangulation. Unfortunately the method fails in the case of Mars because of the great distance we are away. Unless the planet were distinctly more generously equipped than the earth in the matter of mountains, nothing could be hoped from so forthright an envisaging. So relatively insignificant to the size of its globe is the relief of the earth's surface that an orange skin would seem grossly rough by comparison. The same proves true for Mars. With the greatest magnification we can produce, the Martian limb still appears perfectly smooth.

Luckily, while direct vision is thus impossible, oblique illumination enables us to get an insight into the character of the surface we had otherwise been denied. When mountains or valleys chance to lie upon the boundary of light and darkness, the rim of the disk known as the terminator in contradistinction to the limb where the surface itself comes to an end, they make their presence evident through an indirect species of magnification, the elongate effect of oblique lighting. With a practical instance of it every one is familiar who has walked by night along a road imperfectly starred at intervals by electric lights. Startled between posts by what seemed deep holes and high furrows he has involuntarily imitated a spavined horse for fear of stubbing his toes, only to encounter when

his foot fell a surface on contact surprisingly smooth. The slant illumination by lengthening the shadows had painfully deceived him into exaggerated inference of irregularity. What proves disturbing to a wayfarer misguided by arc lights is made to do the eye service when it comes to planetary interpretation. On the boundary of light and shade, those parts of the surface where it is sunrise or sunset upon the planet, the sun's rays fall so athwartwise as to throw enormous shadows from quite small elevations to an eye so placed as to view the surface with anything approaching perpendicularity. A mountain mass there will thus proclaim itself by protracted profile upon the plain in hundredfold magnification. Similarly a peak there will advertise its height by catching the coming or holding the lingering light at many times the distance of its own elevation away from the night side of the planet. Here, if anywhere, then, could mountains be expected to disclose themselves, and here, when existent, they have as a matter of fact been found.

Our own moon offers us the first and easiest example of such vicariously visible relief. When the moon is near the quarter, and for three or four days on either side of that, a keen eye can usually detect one or more knobs, like warts, projecting from its terminator, easily distinguished from the limb both by reason of

being less bright and of being bounded by a semi-ellipse instead of a semicircle. If a telescope or even an opera-glass be substituted for the eye, it is possible to see what causes them; the knob resolves itself into the illuminated rim of a crater separated from the main body of the visible moon by the seemingly black void of space. The peak has caught the sunlight, while its foot and the country between it and the illuminated surface still lies shrouded in shadow.

From measurement of the distance the sun-tipped peak seems to stand aloof from the line where the plain itself is touched by the light, the height of it above that plain may be calculated. In this way have been found the heights of the mountains of the moon. Incidentally, brain outstrips brawn. For pinnacles no Lunarian could scale, both for their precipitous inaccessibility and their loftiness, man has measured without so much as setting foot upon their globe. At each lunar sunrise and again at lunar sunset these old crater walls show their crescent coronets tipped the reverse way; and peaks higher than the Himalayas make gigantic gnomons of themselves with hands outstretched to grasp the plains.

In this manner a lunar peak of fifteen thousand feet shows its presence to the unaided eye. With so much for starting-point we can calculate how low an elevation could similarly be made out on Mars under a like

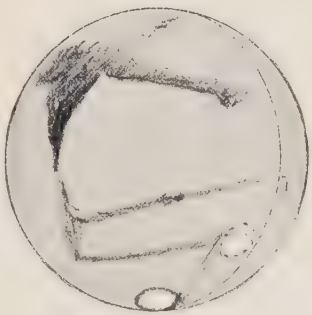
phase illumination. Now, in spheres of different diameters the distance out from the terminator for a given height is as the square root of the diameter. Mars has about twice the size of the Moon. In consequence, if we saw the planet at the same distance off as the Moon, the height of a peak upon it sufficient to cast an equal shadow or be seen at an equal separation from the terminator need be but two thirds as high. To see it thus equidistant a power of 250 or 300 is necessary, dependent on the opposition. Twice this power may at times be used, and by the same reasoning this would reduce the height sufficient to show by four or to something like 2500 feet. This, then, would be the theoretic limit of the visible, a limit needing to be somewhat increased because of the imperfection of our air.

Having found thus what should be visible on Mars we turn now to see what is. At once we find ourselves confronted with a very unlunar state of things. Common upon the face of the Moon, excrescences of the terminator are rare on Mars. The first ever seen was detected by a visitor at the Lick Observatory in 1888. Since then they have been repeatedly noticed both at the Lick and elsewhere. But although observers are now on the watch for them, they are not very frequently chronicled because not of everyday occurrence. Much depends upon the opposition; some approaches

of the planet proving more prolific of them than others. How rare they are, however, may be gathered from the fact that the last three oppositions have disclosed but one apiece.

An account of the great projection of May 25, 1903, will give an idea of the extent and interest of the phenomenon and will serve to show to what cause we must attribute all such that have been visible on Mars, for the behavior of this one was typical of the class.

About half past eight o'clock in the evening of May 26, 1903, Mr. V. M. Slipher, astronomer at Flagstaff, shortly after taking over the telescope then directed upon Mars, suddenly noticed a large projection about halfway up the terminator of the planet. He at once sent word of the fact and the observatory staff turned out to see it, for a projection has for workers on Mars the like interest that a new comet possesses for astronomers generally. In this case the phenomenon was specially potent in that it was the first to be detected that year. Its singularity was amply seconded by its size. For it was very large, its extent both in length and height being excessive. When I first saw it, the projection consisted of an



Projection on terminator.

oval patch of light, a little to the north of the centre of the phase ellipse lying parallel to the terminator but parted from it by darkness to the extent of half the projection's own width. It made thus not simply an excrescence but a detached islet of light. It was easily seen by all those present and was carefully studied from that time on by Mr. Slipher and me. Both of us made drawings of it alternately at intervals, as well as micrometer measures of its position.

Next to its great size, the most striking feature about it was its color. This, instead of being white or whitish, was ochre orange, a hue closely assimilated to the tint of the subjacent parts of the disk, which was the region known as Chryse. This distinctive complexion it kept throughout the period of its apparition. At the same time Baltia, a region to the north of it and synchronously visible close upon the terminator, showed whitish. The seeing was good enough to disclose the Phison and Euphrates double, the power a magnification of 310 and the aperture the full aperture of the 24-inch objective.

From the time it was first seen the detached patch of light crept in toward the disk, the illuminated body of the planet. Four minutes after I noted it the dark space separating it from the nearest point of the terminator had sensibly lessened. So it continued, with some fluctuations intrinsic to the atmospheric diffi-

culties of observations generally and to the smallness of the object itself, to become gradually less and less salient. It lasted for about forty minutes from the moment it had first appeared to Mr. Slipher and then passed from sight to leave the edge of the planet smooth and commonplace again.

The measures made on it showed that it lay when first seen in longitude 39°.7, latitude 18°.5 north, and that its highest point stood seventeen miles above the surface of the planet. It was three hundred miles long. These are my own figures, from which Mr. Slipher's do not substantially differ.

The return of the part of the planet where it had been seen was eagerly awaited the night after by both observers, to see if it would bring the projection with it. For only once a day is the same region of Mars similarly presented. But in order not to miss the projection, should it be ahead of time, observations were begun before it was due. Shortly after they were started, there appeared higher up the terminator and therefore farther north than had been the case the night before, a small projection. It was with difficulty made out and its position measured. Without careful watching it must have been missed altogether. As it was, it differed in every respect from that of the preceding day. It was not nearly so high, not nearly so large, and lay in a different place on the planet, being now

in longitude 31°.7, latitude 25°.5. Either the two, therefore, were totally different things or the projection had moved in the elapsed interval of time over seven degrees of latitude and eight degrees of longitude, a distance of three hundred and ninety miles in twenty-four hours. Where the previous projection had been nothing showed. On the following night, May 28, no trace of anything unusual could be seen anywhere.

We are now concerned to inquire to what this series of appearances could have been due. The first observers of projections on Mars had unhesitatingly attributed them to the same cause that produces projections on the Moon, to wit, mountains. Such they were held to be in France and at the Lick. This view, however, was in 1892 disputed by W. H. Pickering who considered them to be not mountains, but cloud. And this view was strongly supported by A. E. Douglass in a discussion of a large number of them observed in 1894 at Flagstaff. The mountain theory of their generation was finally shown to be untenable and their ascription to cloud conclusively proved to be the correct solution by the observations of a remarkable one made in December, 1900, and the careful study to which by the writer they were subjected. We shall now explain how this was done and we will begin by pointing out that the fact that only a single specimen of the phenomenon was visible at each of the

three oppositions of 1900, 1903, and 1905 was itself conclusive, rightly viewed, of their non-mountainous character. This conclusion follows at once from the isolateness of the phenomenon. For a mountain cannot change its place. Now, the shift in the aspect presented by the planet's disk from one night to the next is not sufficient to alter perceptibly the appearance shown by anything upon its edge on the two occasions. If, then, a peak stood out upon it one evening, the peak should again show salient when the region reached the same position upon the succeeding night. That nothing then was seen where something had previously been visible proved the phenomenon not that of a mountain peak, since what produced the projection was clearly not fixed in place and therefore not attached to the soil. Now the only other thing capable of catching the light before it reached the surface would be something suspended in the air, that is, a cloud. Deduction, therefore, from the rarity of the phenomenon alone showed that the projections must be clouds.

Their behavior in detail entirely corroborates this deduction from their intermittence. Such was shown by the action of the projection of December 6, 1900, as set forth in a paper before the American Philosophical Society and such again by that of the one of May 26, 1903, as we shall now note. To begin with, we notice that the projection seen on May 26 was not

found either *in situ* or in size on May 27 and had wholly vanished on May 28, though the seeing was substantially the same if not better on the two nights succeeding that of its original detection. Hence in its own instance this projection proved an alibi irreconcilable with the character of a mountain mass. But it did more. It not only was not on the second evening what and where it had been on the first, but the remains of it visible on the second occasion showed clearly that it had moved in the meantime. Furthermore it was disappearing as it went, for it was very much smaller after the lapse of twenty-four hours. The something that caused it was not only not attached to the soil, but was moving and dissipating as it moved. Only one class of bodies known to us can account for these metamorphoses and that is: cloud.

But what kind of cloud are we to conceive it to be? Our ordinary vapor clouds are whitish and this would be still more their color could they be looked at from above. The Martian cloud was not white but tawny, of the tint exhibited by a cloud of dust. Nor could this color have very well been lent it by its sunrise position, for other places equally situated to be tinged by the hues of that time of day, Baltia to wit, showed distinctly white. So that we must suppose it to be what it looked, a something of the soil, not beholden to atmospheric tinting for its hue; a vast dust-cloud

traveling slowly over the desert and settling slowly again to the ground.

Precisely the same general course of drifting disappearance was taken by the projection of December 7 and 8, 1900. And this, too, stood an unique apparition in the annals of its opposition. Clouds, then, and not mountains are the explanation of the projections on Mars, differing thus completely from the lunar ones.

CHAPTER X

THE BLUE-GREEN AREAS

DESCENDING now equatorwards from the polar regions, and their in part paleocrystic, in part periodic, coating of ice, we come out upon the general uncovered expanse of the planet which in winter comprises relatively less surface than on Earth, but in summer relatively more. Forty degrees and eighty-six degrees may be taken as the mean hiemal and æstival limits respectively of the snow on Mars; forty-five and seventy-five as those of the Earth. Whatever ground is thus bared of superficial covering on Mars lies fully exposed to view, thanks to the absence of obscuring cloud; and it is at once evident that the terrrane is diversified, patches of blue-green alternating with stretches of reddish ochre. Of the two opaline tints the reddish ochre predominates, fully five eighths of the disk being occupied by it.

It was early evident in the study of the surface of Mars that its ochreish disk was not spotless. Huyghens in 1659 saw the Syrtis Major. From this first fruit of areography dates, indeed, the initial recognition of the planet's rotation; for on noting that

the marking changed its place, he inferred a turning of the planet upon itself in about twenty-four hours. Thirteen years later he observed and drew it again and this time in company with the polar cap. Again, after eleven more years, he depicted it for the third time, and now so changed because of the different tilt of the planet toward the earth that it may be doubted whether Huyghens himself recognized it for the same. But that he drew it correctly a globe of Mars will at once show.

From such small beginning did areography progress to the perception of permanent patches of a sombre hue distributed more or less irregularly over the disk. Impressing the observers simply as dark at first, they later came to be recognized as possessing color, a blue-green, which contrasted beautifully with the reddish ochre of the rest of the surface. Cassini, Maraldi, Bianchini, Herschel, Schroeter, all saw markings which they reproduced. Finally, with Beer and Maedler, came the first attempt at a complete geography. In and out through the ochre was traced the blue; commonly in long Mediterraneans of shade, but here and there in isolated Caspians of color. With our modern telescopic means the dark patches are easily visible, the very smallest glass sufficing to disclose them. When thus shown they much resemble in contour the dark patches on the face of the Moon as seen with the naked eye. Now these patches were early taken for lunar

seas and received names in keeping with the conception; as the Sea of Serenity, the Sea of Vapors, and so forth. Following the recognition of a like appearance, like appellatives were given to the Martian markings; and the Mare Sirenum, or Sea of the Sirens, the Mare Cimmerium, and others sufficiently proclaim what was thought of them at the time they were thus baptized. Indeed, if a general similarity be any warrant for a generic name they were not at the time ill-termed. For, common to all three bodies, the Earth, the Moon, and the planet Mars, is the figuration of their surfaces into light areas and dark. In the Martian disk, as in the lunar one, we seem to be looking at a cartographic presentation of some strange geography suspended in the sky; the first generic difference between the two being that the chart is done in chiaroscuro for the Moon, in color for Mars. On mundane maps, we know the dusky washes for oceans; so on the Moon it was only natural to consider their counterparts as *maria;* and on Mars as 'seas.' Nor did the blue-green hue of the Martian ones detract from the resemblance.

But in something other than color these markings are alike. In fact, color could hardly be excuse for considering the lunar *maria* what their name implies, for distinctive tint is lacking in them, even to the naked eye. It was in form that the likeness lay. Their figures were such as our own oceans show; and allowing for

a sisterly contrast amid a sisterly resemblance, the lunar *maria* or the Martian seas might well have been of similar origin to those with which our schoolboy study of atlases had made us familiar. Thus did similarity in look suggest similarity in origin, and intuitive recognition clothe its objects with the same specific name.

Considerable assumption, however, underlay the pleasing simplicity of the correlation on other grounds, consequent not so much upon any lack of astronomic knowledge as, curiously, upon a dearth of knowledge of ourselves. We know how other bodies look to us, but we ignore how we look to them. It is not so easy to see ourselves as others see us; for a far view may differ from a near one, and a matter of inclination greatly alter the result. Owing both to distance and to tilt we lack that practical acquaintance with the aspect of our own oceans viewed from above, necessary to definite predication of their appearance across interplanetary space. Our usual idea is that seas show dark, but it is also quite evident that under some circumstances they appear the contrary. It all depends upon the position of the observer and upon the position of the Sun. Their usual ultramarine may become even as molten brass from indirect reflection; while on direct mirroring, they give back the Sun with such scarce perceptible purloining of splendor as to present a dazzling sheen

not to be gazed upon without regret. Canopied by a welkin they assume its leaden hue, while at the same time, their shores, less impressionable to borrowed lighting, show several tints darker than themselves. Surfaces so sensitive to illumination hardly admit of more accusable tint than a chameleon. Nevertheless, we are probably justified in our conviction that perpendicularly visaged, they would on the whole outdo in sombreness land round about them, and so be evident as dusky patches against a brighter ground.

One phenomenon we might with some confidence look to see exhibited by them were they oceans, and that is the reflected image of the Sun visible as a burnished glare at a calculable point. Specular reflection of the sort was early suggested in the case of Mars, and physical ephemerides for the planet registered for many years the precise spot where the starlike image should be sought. But it was never seen. Yet not till the marine character of the Martian seas had been otherwise disproved was the futile quest for it abandoned. Indeed, it was a tacit recognition that our knowledge had advanced when this column in the ephemeris was allowed to lapse.

On this general marine ascription doubt was first cast in the case of the Moon. So soon as the telescope came to be pointed at our satellite, it was evident that the darker washes were not water surfaces at all, but

very palpably plains. Long low ridges of elevation stood out upon them like prairie swells, which grew in visible relief according to the slanting character of the illumination. Cracks or rills, too, appeared near their edges and craters showed in their very midst. Patently solid they betrayed their constitution not only by diverse topography but by diversified tint. All manner of shades of neutral tone mottled their surface, from seeming porphyry to chalk. Belief perforce departed when the telescope thus pricked the bubble, evaporating as the water itself had done long before.

So much was known before the Mars' markings were named. Nevertheless, humanity, true to its instincts, promptly proceeded to commit again the same mistake, and, cheerfully undeterred by the exposure of its errors in the case of the Moon, repeated the christening in the case of Mars. So sure was it of its ground that what it saw was not ground, that though the particular appellatives of the several seas were constantly altered, rebaptisms, while changing the personal, kept the generic name. Dawes' Ocean, for example, later became l'Ocean Newton and later still the Mare Erythraeum, but remained set down as much a sea as before. About thirteen years ago, however, what had befallen the seas of the Moon, befell those of Mars: the loss of their character. It was first recognized through a similar exposure; but the fact was led up to and might

have been realized in consequence of quite a different line of evidence. The initial thing to cast doubt upon the seas being what they seemed to be was the detection of change in their aspect. That the detection was not made much earlier than actually happened shows how a phenomenon may elude observation if scrutiny be not persistent, and its results from time to time not carefully compared. Schiaparelli was the one who first noticed variation in the look of the seas, and the discovery was as much due to the assiduity with which he followed the planet opposition after opposition as to the keenness with which he scanned it. The noting of change in the blue-green areas constituted, in fact, one of the first fruits of systematic study of the planet. Change in configuration, that is, alteration of area, preceded in recognition alteration of tint. Thus the Syrtis Major showed larger to him in 1879 than it had in 1877. This was natural; difference of degree being a more delicate matter to perceive than its effect upon extent. From change of area his perception went on to change of tone. In his own words, what he noticed was this: *Memoria*, VI, 1888, "No less certain is it that, from one opposition to another, one notices in the seas, very remarkable alterations of tone. Thus the regions called Mare Cimmerium, Mare Sirenum, and Solis Lacus, which during the years 1877 to 1879 could be numbered among the most sombre on the planet,

during the succeeding oppositions became less and less black, and in 1888 were of a light gray hardly sufficient to render them visible in the oblique position in which all three found themselves. . . . On the other hand, at the very same moment, the Mare Acidalium and the Lacus Hyperboreus showed very dark; the latter indeed appeared nearly black, although seen as tilted as the Syrtis and the equatorial bays. The condition of the regions called seas is therefore not constant: so much is unquestionable. Perhaps the change produced in them has to do with the season of the planet's year."

Holding as he did the then prevailing view that the blue-green regions were bodies of water, he regarded those of intermediate tint as vast marshes or swamps, and he accounted for change of hue in them as due to inundations and occasions of drying up. In consequence of losing their water, the seas, he thought, had in places become so shallow that the bottom showed through.

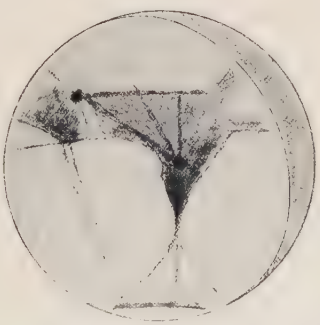
Plausible on the surface, this theory breaks down so soon as it is subjected to quantitative criticism. For the moment we try to track the water, we detect the inadequacy of the clew. The enormous areas over which the phenomenon occurs necessitates the establishing an alibi for all the lost water that has gone. Drying up on such a scale would mean the removal of many feet of liquid over hundreds of thousands of

miles in extent. To produce any such change in appearance as we witness, even on the supposition that these seas were none too deep to start with, would involve lowering the level of the water by from five to twenty feet throughout two thirds of the whole surface of the southern hemisphere. This would leave a heap of waters to be accounted for, bewildering in its immensity. The myriad tons of it must be disposed of; either by drainage into other regions or by being caught up into the sky.

In this emergency it might seem at first as if the polar cap of the opposite hemisphere offered itself as a possible reservoir for the momentarily superfluous fluid. But such hoped-for outlet to the problem is at once closed by the simple fact that when the lightening of the dark regions of the southern hemisphere takes place, the opposite polar cap has already attained its maximum; in fact, has already begun to melt. It, therefore, absolutely refuses to lend itself to any such service. This was not known to Schiaparelli's time, the observations which have established it, by recording more completely the history of the cap, having since been made. Indeed, it was not known even at the time when the writer, in 1894, showed the impossibility of the transfer on other grounds; to wit, on the fact of no commensurate concomitant darkening of the surface elsewhere and on the manifest non-complicity, if not impotency, of the Mar-

tian atmosphere in the process. The transference of the water to other dark patches in the northern hemisphere fails of sufficiency of explanation because of the limited extent of such areas on that side of the globe; while the air is quite as incapable of carrying away any such body of liquid, though the whole of it were at the saturation-point, not to mention that there exists no sign of the attempt. The reader will find this reasoning set forth in *Mars*, published eleven years ago. He will now note, from what has been said above about the northern polar cap, that continued observations since have resulted in opening up another line of proof which has only strengthened the conclusion there reached.

The *coup de grâce*, however, to the old belief was given when the surface of the dark areas was found to be traversed by permanent lines by Pickering and Douglass. Continued observation showed these lines to be unchangeable in place. Now permanent lines cannot exist on bodies of water, and in consequence the idea that what we looked on there were water surfaces had to be abandoned.



Lines in dark area.

Thus we now know that the markings on both the Moon and Mars which have been called *maria* are not in reality seas. Yet we shall do well still to keep the old-fashioned sonorous names, Mare Erythraeum, Mare Sirenum, and their fellows, because it is inconvenient to change; while, if we please, we may see in their consecrated Latin couching the fit embalming in a dead language of a conception that itself is dead.

CHAPTER XI

VEGETATION

SINCE closer acquaintance takes from the *maria* their character of seas, we are led to inquire again into their constitution. Now, when we set ourselves to consider to what such appearances could be due we note something besides sea, which forms a large part of our earth's surface, and would have very much what we suppose the latter's aspect from afar to be, not only in tone, but in tint. This something is vegetation. Seen from a height and mellowed by atmospheric distance, great forests lose their green to become themselves ultramarine.

To dispossess a previous conception is difficult, but so soon as we have put the idea of seas out of our heads a vegetal explanation proves to satisfy the phenomena, even at first glance, better than water surfaces. In their color, blue-green, the dark areas exactly typify the distant look of our own forests; whereas we are not at all sure that seas would. From color alone we are more justified in deeming them vegetal than marine. But the moment we go farther into the matter the more certain we become of being upon the right road.

With increased detection the markings they reveal and the metamorphoses they undergo, while pointing away from water, point as directly to vegetation. All the inexplicabilities which the supposition of water involves find instant solution on the theory of vegetal growth. The non-balancing of the areas of shading in their shift from one part of the disk to another, no longer becomes a circumstance impossible to explain, but a necessary consequence of their new-found character, denoting the time necessary for vegetation to sprout. The change of hue of vast areas from blue-green to ochre no longer presupposes the bodily transference of thousands of tons of substance, but the quiet turning of the leaf under autumnal frosts. Even the fact that they occupy those regions most fitted by figure to contain oceans fits in with the same conception. For that the Martian equivalents of forest and moorland, tree and grass, should grow now in the lowest parts of the planet's surface is what might not unreasonably be expected from the very fact of their being low, since what remained of the water would tend both on the surface and in the air to drain into them.

For the change in question to be vegetal it must occur at the proper season of the planet's year. This we must now consider. We have said that Schiaparelli detected change in the blue-green regions and suspected this change of seasonal affiliation. He inferred this

Mare Erythraeum
Martian date. December 30

Mare Erythræum
Martian date. December 30

from piecing together the aspects of different seasons of different years as shown in consecutive Martian oppositions. To mark it actually take place in a single Martian year came later. In 1894, at Flagstaff, the southern hemisphere was presented during its late spring and early summer; it was observed, too, for many of our months in succession. During this time the planet was specially well circumstanced for study of the change in that hemisphere, both by reason of the appositeness of the season and of the unusual size of the disk. Advantage was taken of the double event to a recording of the consecutive appearances certain regions underwent, and the contrasted states thus exhibited were such as clearly to betoken the action of seasonal change. What Schiaparelli had thus ably inferred from diverse portions of different Martian years was in this case shown occurring in one and the same semestral cycle.

Usually the change of hue seems essentially one of tone; the blue-green fades out, getting less and less pronounced, until in extreme cases only ochre is left behind. It acts as if the darker color were superimposed upon the lighter and could be to a greater or less extent removed. This is what Schiaparelli noted and what was seen in 1894 at Flagstaff. Three views *en suite* of the chain of changes then observed are shown in *Mars*, the region known as Hesperia being central

in each. Comparison of the three discloses a remarkable metamorphosis in that "promontory," a rise into visibility by a paling of its complexion. Nor is the contrast confined to it; changes as salient will be noticed in the pictures over the other parts of the disk.

There have been instances, however, of a metamorphosis so much more strange as to deserve exposition in detail; one where not tone simply is involved, but where a quite new tint has surprisingly appeared.

On April 19, 1903, when, after being hidden for thirty days, owing to the different rotation periods of the two planets, the Mare Erythraeum, the largest blue-green region of the disk and lying in the southern hemisphere, rounded again into view, a startling transformation stood revealed in it. Instead of showing blue-green as usual, and as it had done six weeks before, it was now of a distinct chocolate-brown. It had been well seen at its previous presentation, so that no doubt existed of its then tint. At that time the Martian season corresponded to December 30 in our calendar. Eighteen Martian days had since elapsed, and it was now January 16 there. The metamorphosis had taken place, therefore, shortly after the winter solstice of that part of the planet. The color change that had supervened proved permanent. For the next night the region showed the same brown hue, and so it continued to appear throughout the days that it was visible.

Mare Erythraeum
Martian date. January 16

Mare Erythræum
Martian date, January 16

Two months passed, and then the chocolate hue had vanished, — gone as it had come, — and the *mare* had resumed its usual tint, except for being somewhat pale at the south. It had come to be February 21 on Mars. Timed and tabulated, the metamorphosis through which the *mare* passed stands out thus: —

MARE ERYTHRAEUM 1903

MUNDANE DATE	DAYS BEFORE OR AFTER SUMMER SOLSTICE (BEFORE = −, AFTER = +)	MARTIAN DATE	ASPECT
February 16	−10	December 16	Blue-green
March 20	+22	January 1	Blue-green
April 19	52	January 16	Chocolate
April 22	55	January 18	Chocolate
May 26	89	February 4	Faint chocolate
May 30	93	February 6	Faint chocolate
June 30	123	February 22	Faint blue-green
July 7	130	February 25	Faint blue-green

The culmination of the transformation seems to have taken place about 60 days after the southern winter solstice, or in the depth of the Martian winter of that hemisphere. This is certainly just the time at which vegetation should be at its deadest.

The northern and southern portions of the *mare* did not behave alike in taking on the chocolate tint. From the notes made about them during the opposition it appears that the latter was later than the former in

undergoing the metamorphosis, as will be seen from the following depth of the blue green estimated in percentages shown at different dates, calling the deepest tone ever exhibited by it unity.

Martian Date,	December (16)	January (1)	January (17)	February (5)	February (24)
	%	%	%	%	%
Northern	50	50	0	25	50
Southern	50	50	0	0	25

From this table we may place the lowest point of the blue-green tint as reached about the 22d of January for the northern, the 5th of February for the southern, part. This would indicate that the wave of returning growth came from the north, not the south; an important fact, as we shall see later in studying the action of the canals.

At the next opposition, in 1905, a recurrence of the transformation was watched for, and not in vain. It occurred, however, somewhat later in the Martian season. On December 27 of the planet's current year the Mare Erythraeum was still as usual, blue-green, nothing out of the ordinary being remarked in it; and so it was on its January 17, although the southern edge was darker than the northern. It looked certainly as if the metamorphosis were this year to be omitted. But such was not the case. When the region again came round, on February 1 of the Martian calendar, there the strange

Mare Erythraeum
Martian date, February 1

undergoing the metamorphosis, as will be seen from the following depth of the blue green estimated in percentages shown at different dates, calling the deepest tone ever exhibited by it unity.

Martian Date	December 26	January 1	January [illegible]	[illegible]	[illegible]
	%	%	%		
Northern	50	50	[illegible]	[illegible]	[illegible]
Southern	50	50	[illegible]	[illegible]	[illegible]

[illegible] we may place the lowest point of the [illegible] about the 22d of Janu[illegible] the 5th of February for the [illegible] indicate that the wave [illegible] the north, not the south; [illegible] see later in studying the [illegible]

[illegible] 1905 a recurrence of the [illegible] was [illegible] for, and not in vain. It [illegible] however, somewhat later in the Martian sea[illegible] December 27 of the planet's current year the [illegible] was still as usual blue-green, nothing [illegible] ordinary being remarked [illegible]; and so it was [illegible] 17, although the southern edge was darker [illegible] northern. It looked certainly as if the meta[illegible] were this year to be omitted. But such [illegible] the case. When the region again came round, [illegible] 1 of the Ma[illegible] there the strange

Mare Erythræum
Martian date, February 1

tint was as unmistakable as it had been on its original occurrence. Not only was the Mare Erythraeum so colored, but on February 5 (Martian) the northern portion of the Mare Cimmerium was observed to be similarly affected. In the Mare Erythraeum the anomalous chocolate hue was confined to a belt between the latitudes of 10° and 20° south of the equator; in the Mare Cimmerium it stretched a little higher, from 10° at the west to 25° at the east. It is noteworthy that the southern portion of the latter showed blue at the time the northern showed brown. Then the metamorphosis proceeded as shown in the following table:—

MARE ERYTHRAEUM 1905

MUNDANE DATE	DAYS AFTER WINTER SOLSTICE OF SOUTHERN HEMISPHERE	MARTIAN DATE	ASPECT
January 25	12	December 27	Blue-green
March 6	52	January 16	Blue-green
April 4	81	January 31	Chocolate
April 12	89	February 4	Chocolate
April 30	107	February 13	Faint chocolate
May 8	115	February 17	Faint chocolate
May 12	119	February 19	Faint blue-green
June 11	149	March 6	Faint blue-green
June 15	153	March 8	Faint blue-green
July 16	184	March 23	Pale bluish green

Here, as in 1903, a chromatic rise and fall is evident; the culmination of the change occurring in Martian early February about ninety days after the winter solstice. That it was not of long duration is also indicated. If

we examine the evidence for the two portions of the *mare* separately, the northern and the southern, as in 1903, we find it as follows: —

Martian Date,	December (27)	January (16)	February (2)	February (16)	March (7)	March (23)
	%	%	%	%	%	%
Northern	50	50	0	10	25	30
Southern	50	50	20	20	25	30

Here again a slight retardation in the advent of the metamorphosis is observable in the southern portion.

There would seem to be a difference in the time of the change between the two years of fifteen days, 1905 being by that much the later. But with points of reference themselves thirty days apart, it is possible the two more nearly coincided than here appears.

Unlike the ochre of the light regions generally, which suggest desert pure and simple, the chocolate-brown precisely mimicked the complexion of fallow ground. When we consider the vegetal-like blue-green that it replaced, and remember further the time of year at which it occurred upon both these Martian years, we can hardly resist the conclusion that it was something very like fallow field that was there uncovered to our view.

From the recurrence of the phenomenon on two successive years, it is likely that it annually takes place.

Mare Erythraeum
Martian date, February 21

Mare Erythræum,
Martian date, February 21

That it is seasonal can scarcely be doubted from the timeliness of its occurrence, and that different portions of its terrane successively underwent their metamorphosis shows further that it followed a law peculiar to the planet, to which we shall be introduced when we come to consider the phenomena of the canals.

Instances of relative hue in different dark patches corroboratory of seasonal variation, and therefore of vegetal constitution, might easily be adduced. Thus, in 1905 during the summer of the northern hemisphere, the Mare Acidalium was notably darker than the Mare Erythraeum to the north of it, which is what the law of seasonal variation would require, since it was June in the one, December in the other at the time. But we need not to add example to example or proof to proof, for there are no phenomena that contradict it. We conclude, therefore, that the blue-green areas of Mars are not seas, but areas of vegetation. Just as reasoning to a negative result drifts us to the first conclusion, so reasoning to a positive one lands us at the second.

CHAPTER XII

TERRAQUEOUSNESS AND TERRESTRIALITY

WITH the vanishing of its seas we get for the first time solid ground on which to build our Martian physiography. The change in *venue* from oceans to land has produced a complete alteration in our judgment of the present state of the planet. It destroys the analogy which was supposed to exist between Mars and our earth, and by abolishing the actuality of oceans there, seems, metaphorically, to put us at first all the more at sea in our attempt to understand the planet. But looked at more carefully, it turns out to explain much that was obscure, and in so doing gives us at once a wider view of the history of planetary evolution.

The trait concerned is cosmic. Study of the several planets of our solar system, notably the Earth, Moon, and Mars, reveals tolerably legibly an interesting phase of a planet's career, which apparently must happen to all such bodies, and evidently has happened or is happening to these three: the transition of its surface from a terraqueous to a purely terrestrial condition. The terraqueous state is well exhibited by our own earth at the moment, where lands and

oceans share the surface between them. The terrestrial is exemplified by both the Moon and Mars, on whose surfaces no bodies of water at present exist. That the one state passes by process of development into the other I shall now give my reasons for believing.

In the first place the appearance of the dark markings both on the Moon and Mars hints that though seas no longer, they were seas once upon a time. On the moon, not only does their shape suggest this previous condition, but the smooth and even look of their surfaces adds to the cogency of the inference. More important, however, than either of these characteristics, and confirmatory of both, is the fact that the great tracts in question seem to lie below the level of the corrugated surface, which is thickly strewn with volcanic cones. Their level and their levelness fay in explanation into one another. The first makes possible the former presence of water; the second speaks of its effect. For their flat character hints that these areas were held down at the time when the other parts of the surface were being violently thrown up. That they can themselves be cooled lava flows, their extent and position seem enough to negative; to say nothing of the fact that they should in that case lie above, not below, the general level. Something, therefore, covered them during the moon's eruptive youth and

disappeared later. Such superincumbence may well have been water, under which the now great plains lay then as ocean bottoms. Deep-sea soundings in our own oceans betray an ocean floor of the same extensive sort, diversified as on the moon. To call the lunar *maria* seas may not be so complete a misnomer after all; but only a resurrecting in epitaph what was the truth in its day.

Only doubtfully offered here for the Moon, for Mars the inference seems more sure. Here again the dark regions not only look as they should had they had an earlier history, but they, too, seem to lie below the level of the surface round about. When they pass over the terminator they invariably show as flattenings upon it, as if a slice of the surface had been pared off. Such profile in such pass is what ground at a lower level would present. Undoubtedly a part of the seeming depression is due to relative absence of irradiation consequent upon a more sombre tint, but loss of light hardly seems capable of the whole effect. In the case of Mars, then, as with the Moon, a mistaken inference builded better than it knew, if, indeed, we should rightly consider an inference to be mistaken which on half data lands us at the right door.

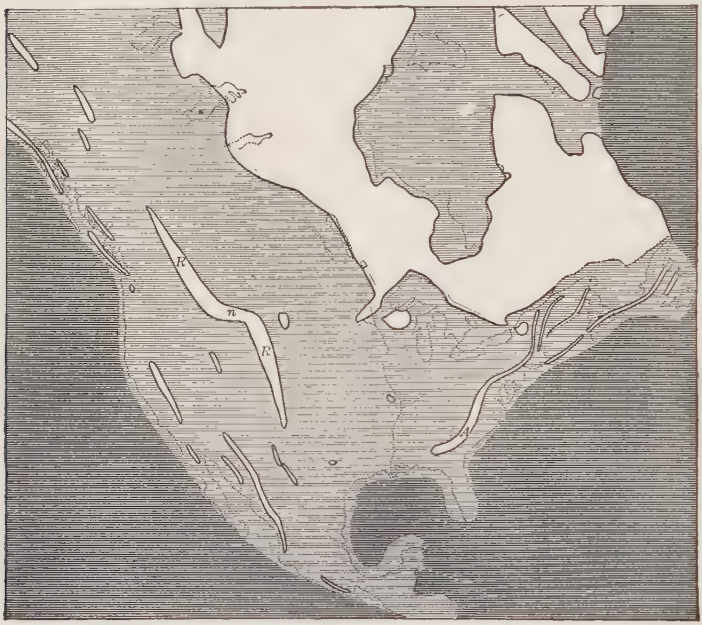
From the aspects of the dark regions we are led, then, to regard Mars as having passed through that stage of existence in which the earth finds itself at the mo-

ment, the stage at which oceans and seas form a feature of its landscape and an impediment to subjugation of its surface in its entirety. What once were ocean beds have become ocean bottoms devoid of that which originally filled them.

That the process of parting with a watery envelop is an inevitable concomitant of the evolution of a planet from chaos to world, we do not have to go so far afield as Mars and the Moon for testimony. Scrutiny reveals as much in the history of our own globe. Two sign-posts of the past, one geologic, the other paleontologic, point unmistakably in this direction. The geologic guides us the more directly to the goal.

Study of the earth's surface reveals the preponderating encroachment of the land upon the sea since both began to be, and demonstrates that, except for local losses, the oceans have been contracting in size from archaic times. So much is evidenced by the successive places upon which marine beds have been laid down. This suggests itself at once as a theoretic probability to one considering the matter from a cosmic standpoint, and it is therefore the more interesting and conclusive that, from an entirely different departure-point, it should have been one of the pet propositions of the late Professor Dana, who worked out conclusively the problem for North America, and published charts detailing the progressive making of that continent.

So telling is this reclaiming by nature of land from the sea that it will be well to follow Dana a little into detail, as the details show effectively the continuity of the process acting through æons of geologic time. At



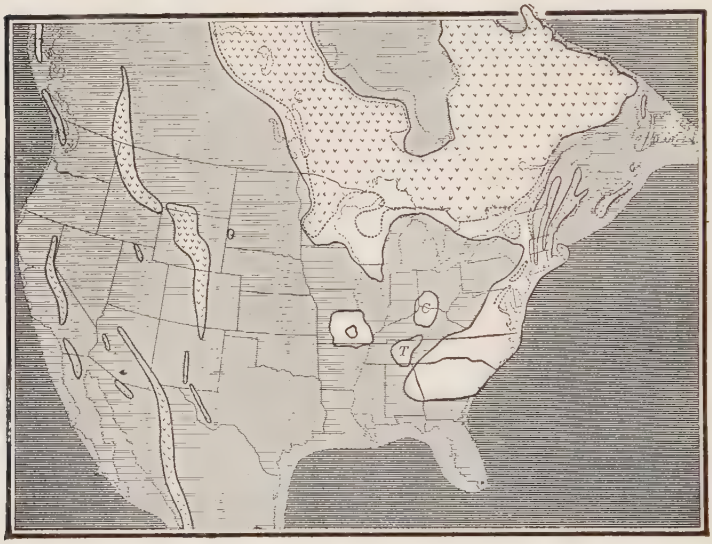
Map of North America at the close of Archæan time, showing approximately the areas of dry land. (From Dana's "Manual of Geology.")

the beginning of the Archæan age, or, in other words, at the epoch when stratified beds were first laid down, the earth reached a turning-point in its history. Erosion, superficial and sub-aërial, then set in to help restrict the domain of the sea. At this juncture North America consisted of a sickle of terrane inclosing Hud-

son's Bay and coming down at its apex to a point not much removed from where Ottawa now stands, in about latitude 45° — a Labradorian North America only. This, the kernel of the future continent, curiously symbolized the form that continent was later to take. For its eastern edge was roughly parallel to the present Atlantic coastline, although much within and to the north of it, while its western one was similarly aligned afar off to the now Pacific slope. Besides this continent proper, the Appalachian, Rocky Mountain, Sierra Nevada, and Sierra Madre chains stood out of the ocean in long, narrow ridges of detached land, outlining in skeleton the bones of the continent that was to be. The Black Hills of Dakota and other highlands made here and there islets in the sea.

Much the same backbone-showing of continents yet to be filled out was true of Europe, Asia, and South America. In Europe the northern countries constituted all that could be called continental land. Most of Norway, Sweden, Finland, Lapland, existed then, while the northern half of Scotland, the outer Hebrides, portions of Ireland, England, France, and Germany stood out as detached islands. From this, which is a fair sample of the proportion of land then to land now over the other continents so far as they are geologically known, we turn to consider more in detail the history of North America.

By the time the Upper Silurian period came in, the Appalachian highlands there had been greatly extended and joined to the Labradorian mainland by continuous

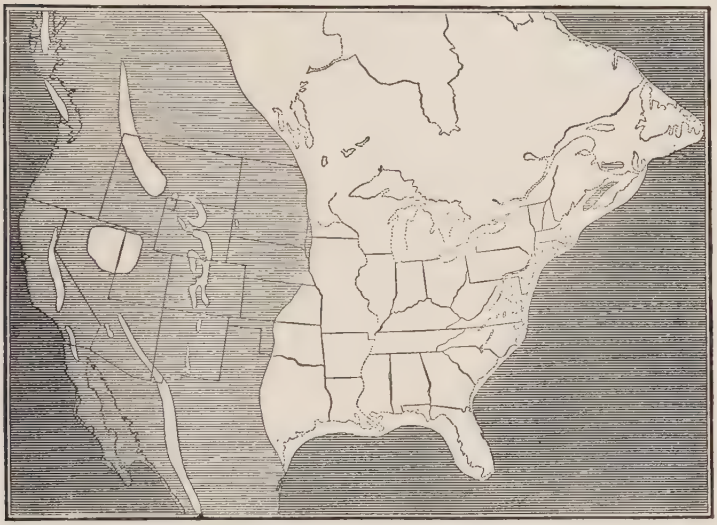


North America at the opening of the Upper Silurian. (From Dana's "Manual of Geology.")

territory; otherwise, no important addition had occurred, though islands emerged in Ohio, Kentucky, and Missouri.

At the commencement of the Carbonic era what are now the Middle states had begun to fill up from the north, and Newfoundland, from a small island in the Upper Silurian, had become a great promontory of Labrador, while the Eastern states region and Nova Scotia had risen into being. The movements closing

Paleozoic time upheaved from low islands the Appalachian chain. The earth's crust here crumpled by contraction upon itself; and the movement ended,



Map of North America after the Appalachian Revolution. (From Dana's "Manual of Geology.")

as Dana says, by making dry land of the whole eastern half of the continent, along substantially its present lines.

Mesozoic time was the period of the making of the West. It was an era of deposition and coincident subsidence, when the western land had its nose just above water at one moment to be submerged the next. Though on the whole this part of the continent was emerging, the fact was that, synchronously with the

sinking of the sea, much of the land from time to time sank too. The contraction which raised the Appalachian Mountains at the beginning of the period and that

North America in the Cretaceous period. (From Dana's "Manual of Geology.")

of the Rockies at its close overdid the necessities of the case and caused subsidence elsewhere. The southeastern portion of the continent suffered most, the West on the whole materially gaining. In the Triassic and Jurassic eras the gain was pronounced; it occurred in the Cretaceous also, but with much alternation of loss. Finally, at the close of the Cretaceous, the continent, except for a prolonged Gulf of Mexico and vast internal lakes, was substantially complete.

The filling up of these lakes and the reclaiming of

land from the Gulf of Mexico constituted the land-making work of Tertiary times. The extent of the lakes in the Eocene era is held to show that the general

Map of North America, showing the parts under water in the Tertiary Era; the vertically lined is the Eocene. (From Dana's "Manual of Geology.")

level of the mountain plateau was low and rose later. So that the gain by the land at this time was greater than the map allows to appear. By the beginning of the Quaternary epoch the continents had assumed their present general area, and since then their internal features have alone suffered change.

A similar rising from the sea fell to the lot of Europe, though it has not been detailed with so much care. The skeleton of that continent was at the beginning of depositary time much what it is to-day, but a great in-

land sea occupied the centre of it, which, as time went on, was gradually silted in and evaporated away, notably during the Upper Silurian period.

From all this it is pretty clear that, side by side with alternating risings and sinkings of the land, there was a tolerably steady gain in the contest by which dry ground dispossessed the sea. We may, of course, credit this to a general deepening of the ocean bottoms due to crumpling of the crust, but we may also impute it to a loss of water, and that the latter is, at least for a part, in the explanation the condition of the Moon and Mars makes probable.

Palæontology has the same story of reclamation to tell as geology, and with as much certainty, though its evidence is circumstantial instead of direct and speaks for the growing importance of the land in the globe's economy since the beginning of depositary time, and thus inferentially to its increasing extent. Fossil remains of the plants and creatures that have one after the other inhabited the earth show that the land has been steadily rising both in floral and faunal estimation as a habitat from the earliest ages to the present day. The record lies imprinted in the strata consecutively laid down, and except for gaps reads as directly on in bettering domicile as in evolutionary development.

In Archæan times we find no undisputed evidence of life either vegetal or animal. But beds of graphite

and of limestone point to the possible existence of both. Even anthracite has been found in Archæan rocks in Norway and also in Rhode Island. Whether Dawson's Eozoon Canadense be a rhizopod or a crystal, doctors of science disagree. Dana, while admitting nothing specific, deems it antecedently probable that algæ and later microscopic fungi related to bacteria existed then, living in water well up toward the boiling-point. Indeed, it is practically certain that invertebrate life existed, because of its already well-developed character in the next era. The like antedating is inferable for the whole record of the rocks. Relatively their history is undoubtedly fairly accurate, but absolutely it must be shifted bodily backward into the next preceding era to correspond with fact not yet unearthed.

In the Lower Cambrian, when first the existence of life becomes a certainty, that life, so far as known, was wholly invertebrate and wholly marine; rhizopods (probably), sponges and corals, echinoderms, worms, brachiopods, mollusks, and crustaceans grew amid primitive seaweed and have left their houses in the shape of shells while perishing themselves. Their tracks too have thus survived. The trilobites, crustaceans somewhat resembling our horseshoe crab, were the lords of the Cambrian seas and marked the point to which organic evolution had then attained. Their aquatic character as well as their simple type is shown

by their thoracic legs having each a natatory appendage.

In the next era, the Lower Silurian, the fauna and flora were still marine, although of a higher order than before, and in the Trenton period, the upper part of the era, the earliest vertebrates, fishes, come upon the scene: ganoids and possibly sharks. Nothing terrestrial of this period has yet with certainty been unearthed in America. Europe would seem to have either been more advanced then or better studied since, for there the first plant higher than a seaweed has been dug up, one of a fresh-water genus betokening the land; while in keeping with this the first insect, an hemipter, also has been disinterred. Both the geography and the life of the Eopaleozoic period Dana styles "thalassic."

Neopaleozoic time, beginning with the Upper Silurian, marked the emergence of the continents, and following them the emergence of life from the water on to this land. In the lower beds of the Upper Silurian in America we find only the aquatic forms of previous strata, but in a higher one we come in marshes upon plants related to the equiseta or horsetails. In England land plants appear for the first time in these latest Silurian beds and in the schists of Angers have been preserved ferns. In both the old world and the new fossil fishes are found and the oldest terrestrial species of scorpions. But the great bulk of forms was

still marine; corals, crinoids, brachiopods, trilobites constituting the principal inhabitants. At this time the seas were warm, having much the same temperature between 65° and 80° north as between 30° and 45°; the prevalence of a general temperate tropicality being shown by the fact that the common tropical chain corals lived in latitude 82° north.

In the Devonian era, the Old Red Sandstone, fishes grew and multiplied, increasing in size apparently through the era, and in the last period of it reaching their culminating point. These pelagic vertebrates much surpassed in structure the terrestrial population of the time, which was of a low type and consisted of invertebrates such as myriapods, spiders, scorpions, and insects; for the land was only making. In the mid-Devonian, forests of a primitive kind covered such country as there was, an amphibious land, composed of jungles and widespread marshes. Tree ferns made the bulk of the vegetation, but among them grew also cycads and yews. Mammoth may-flies flitted through the gloom of these old forests, but no vertebrate as yet had left the sea.

Following upon the Old Red Sandstone were laid down the Carbonic strata, and with the Carbonic entered upon the scene the advance scouts of an army of progress evolutionarily impelled to spy out the land — the first amphibians. They made their début in the

Subcarboniferous section of the era, the oldest of the three periods into which the Carbonic is divided, crawling out of the sea to return again and leaving but footprints at first on the sands of time. In the second period, the Coal-measures proper, they ventured so far as to leave their skeletons on terra firma, or rather infirma, while their tracks there show them to have been now in great numbers. In this manner the ancestors of the oldest land inhabitants began to struggle out of the sea. In the Permian, the third and latest period of paleozoic times, we find their descendants established in their new habitat, for in it we come upon the first reptiles. Such possession marks a distinct step up in function as in fact, for while amphibians visited dry land, reptiles made it their home. The getting out of the water had now, in the case of the more evolved forms, become an accomplished fact. The reptiles were, indeed, the lowest and most generalized of their class, Rhynchocephalians, "beak-headed" species that by their teeth proclaim their marine origin and their relationship to the great amphibians that still felt undecided where to stay. Meanwhile, in Europe dragon-flies, two feet across, possessed the air; while amphibians there, as here, ancestrally preceded reptiles in occupying the land.

Mesozoic times were, *par excellence*, the age of monsters; for the Triassic (the New Red Sandstone),

Jurassic and Cretaceous eras marked the reign of the reptiles. Great dinosaurs sleep still in the Triassic strata of the Atlantic border and in the Jurassic of the Western states, to be unearthed from time to time and be given mausolea in our museums. Gigantic they were and very literally possessed the earth. In Europe they were substantially as in America during these mesozoic eras, and showed their dominance by long survival in time as well as world-wide distribution in space; for they lived all the way from Kansas to New Zealand and from the Trias to the Upper Cretaceous. It is supposed by Professor Osborn that many of them, like the herbivorous brontosaurus, waded in marshes, not wholly unlike in habit to the modern hippopotamus. Others were land-stalking carnivores, like the megalosaurs of a little later date. Of enormous size, the largest exceeded any animal which has ever lived, the whales alone excepted; the biggest, the atlantosaurus and the brontosaurus, reaching a length of sixty feet. For all their bulk they had scant brains, just enough to enable them to feed and wallow, probably. It is interesting to note that many of the reptiles, the less adventurous, apparently reverted to the sea. For though the crocodilians existed already in the Trias, the plesiosaurians did not come in till the Middle Trias in Europe, and the sea-serpents (mosasaurus) till the Upper Cretaceous.

Though the dinosaurs dominated life in those days, higher forms, their descendants, unnoticed were gradually creeping in, eventually to supplant them. For brain was making its way unobtrusively in the earliest of the mammals, diminutive creatures at first and of the lowest type. First appearing in the Trias as something approaching the missing link between reptiles and mammals, they later developed into monotremes and marsupials, not rising in differentiation above the latter order to the end of Mesozoic times. And this both in the old world and the new. In the Jurassic, too, flying lizards and the first birds appeared, showing their pedigree in their teeth.

With Cenozoic times we come upon the first true or placental mammals with their culmination up to date in man. In the Eocene they were of a primitive type; they were also of a comprehensive one, fitted to eat anything. From this they specialized, some evolving and some on the whole devolving; the whale, for instance, taking to the water in the Eocene through the same degenerate proclivity that had characterized the sea-saurians ages before. The earth was growing colder, though still fairly warm, and with the fall in temperature the higher types of life antithetically rose, evolution gradually fitting them to cope with more advanced conditions. In this manner did the land supplant the sea as the essential feature of the earth's surface, first,

in coming into being, and then, by offering conditions fraught with greater possibilities, as the habitat of the most advanced forms of life, both plants and animals.

The possibility of advance in evolution was largely due to the fact that the land did thus supplant the sea. Spontaneous variation, the as yet unexplained *primum mobile* in the genesis of species, is probably to be referred to chemism and is likely later to receive its solution at the hands of that science. In the meanwhile it is evident that unless the variation obtain encouragement from the environment no advance in type occurs. Now the land offers to an organism sufficiently evolved to benefit by it, opportunities the sea does not possess. First of these, undoubtedly, is the care it enables to be given to the young. To cast one's brood upon the waters is not the best method of insuring its bringing up. There is too much of the uncertainties of wave and current to make the process a healthy one, and even when attached to rocks and seaweed, the attachment to a mother is to be preferred. Without a period of infancy, when the young is unable to do for itself, no great development is possible. In the only striking exception, the case of the whales, dolphins, and porpoises, size has probably counted for much in the matter, while the development of the cetaceans is far behind that of the majority of land mammals.

Change of place, not in distance, but in variety, is

another factor. The sea is same as a habitat, one square mile of it being much like another, except for gradually changing temperature. The land, on the other hand, from its accidented surface, presents all manner of diversity in the conditions. And the more varied the conditions to which the organism is exposed, the greater its own complexity must be to enable it to meet them.

That the terrestrial stage of planetary development is subsequent to the terraqueous one, and must of necessity succeed it if the latter ever exist on a body, follows from the loss of internal heat on the one hand and from the kinetic theory of gases on the other. To which of the two to attribute the lion's share in the business is matter for doubt; but that both must be concerned in it we may take for certain.

So long as the internal heat suffices to keep the body fluid, the liquid itself sees to it that all interstices are filled. As the heat dissipates, the body begins to solidify, starting with the crust. For cosmic purposes it undoubtedly still remains plastic, but cracks of relatively small size are both formed and persist. Into these the surface water seeps. With continued refrigeration the crust thickens, more cracks are opened and more water given lodgment within, to the impoverishment of the seas. The process would continue till the pressure of the crust itself rendered plastic all that lay below, beyond which, of course, no fissures could be formed.

How competent to swallow all the seas such earth cuticle cracks may be we ignore; for we cannot be said to know much of the process. We can only infer that to a certain extent internal absorption of surface seas must mark a stage of the evolution by which a star becomes a world and then an inert mass, one of the dark bodies of which space is full.

Of the other means we know more. We are certain that it must take place, though we are in doubt as to the amount it has already accomplished. This method of depletion is by the departure of the water in the form of gas, in consequence of the molecular motions. If we knew the temperature and the age of Mars and also the amount of atmosphere originally surrounding it, we could possibly predicate its state. Reversely, we can infer something as to age and temperature from its present condition.

CHAPTER XIII

THE REDDISH-OCHRE TRACTS

BOTH for their evidence and their extent the great ochre stretches of the disk claim attention first. Largely unchangeable, these show essentially the same day after day and from the year's beginning to its end. In hue they range from sand color to a brick red; some parts of the planet being given to the one tint, some to the other. It is to the latter that the fiery tint of Mars to the naked eye is due. The differences in complexion are local and peculiar, both in place and time. For though saffron best paints the greater part of the light areas, certain localities present at times a red like that of our red sandstone. Hellas is one of these ruddy regions and Aeria another. It is only on occasion that they thus show, and to what to assign their variability is as yet matter of conjecture. Possibly it is owing to Martian meteorologic condition; possibly to something else. But whatever its origin, the change is not so much contradictory of, as supplementary to, the general fact of unalterableness, which is after all the basic trait about them and the keynote to their condition.

Land the ochre regions have generally been taken for, and land they still make good their claim to be considered. For the better they are seen, the greater the ground for the belief. Indeed, they seem to be nothing but ground, or, in other words, deserts. Their color first points them out for such. The pale salmon hue, which best reproduces in drawings the general tint of their surface, is that which our own deserts wear. The Sahara has this look; still more it finds its counterpart in the far aspect of the Painted Desert of northern Arizona. To one standing on the summit of the San Francisco Peaks and gazing off from that isolated height upon this other isolation of aridity, the resemblance of its lambent saffron to the telescopic tints of the Martian globe is strikingly impressive. Far forest and still farther desert are transmuted by distance into mere washes of color, the one robin's-egg blue, the other roseate ochre, and so bathed, both, in the flood of sunshine from out a cloudless burnished sky that their tints rival those of a fire-opal. None otherwise do the Martian colors stand out upon the disk at the far end of the journey down the telescope's tube. Even in its mottlings the one expanse recalls the other. To the Painted Desert its predominating tint is given by the new red sandstone of the Trias, the stratum here exposed; and this shows in all its pristine nakedness because of the lack of water to clothe

it with any but the sparsest growth. Limestones that crop out beside it are lighter yellow, whitish and steel-gray, and seen near give the terrane the look of a painter's palette. Seen from far they have rather the tint of sand; and the one effect, like the other, is Martian in look. And as if to assimilate the two planetary appearances the more, the thread of blue-green that attention traces athwart the Painted Desert marks the line of cottonwoods along the banks of the Little Colorado River — deserts both, if look be any guarantee of character, with verdure banding them.

In other ways these earthly deserts offer a parallel to the Martian. No desert on the Earth is absolutely devoid of life of some kind, vegetal and animal. The worst conditioned are not what one is taught in childhood to believe a desert to be — a vast waste of sand, with a camel and a palm thrown in to heighten the sterility. In all Saharas outside of the pages of the school books some vegetation grows, though it is commonly not of a kind to boast of, being rather a *succés d'estime*, as sagebrush, cacti, and the like. But what is of interest here in the connection is its color. For it is commonly of a more ochreish tint than usual, in keeping with its surroundings, a paling out of the green to something more tawny, indicating a relative reduction of the chlorophyll and an increase of the lipochromes in the tissues of the plant, since the one gives

the green tint to the leaves, the other the yellow. As this vegetation, poor as it is, has its annual history, it must alter the look of the desert at times and produce precisely those slight variations in tint observable on Mars in like circumstance.

The Arizona desert dates from no further back than early Tertiary times, as the limestone of the Cretaceous there present shows. Water then stretched where desert now is, and the limestone beds were laid down in it. How old the Martian Saharas are we have no means of knowing. But one thing we may predicate about both: a desert is not an original, but an acquired, condition of a planet's surface, demonstrably so in the case of a planet which has had a sedimentary epoch in its life-history. In the Arizona desert the surface is composed of depositary rocks of Mesozoic times, except where lava streams have flowed down over it since then. The land, then, was once under water, and cannot but have been fertile for some time after it emerged.

But we are not left to inference in the matter, however good that inference may be. A little to the south of the Painted Desert, in the midst of the barren plateau of northern Arizona, of which the former makes a part, stand the remains of a petrified forest. Huge chalcedony trunks of trees, so savingly transmuted into stone that their genus is still decipherable, lie scattered here

over the barren ground in waste profusion, one of them still spanning a cañon just as it fell in that, to it, destructive day of a far prehistoric past. The rock stratum on which their remains lie is of Triassic and Cretaceous times and the petrifications show that in the Cretaceous a stately forest overspread the land. In those days at least the spot was fertile where now sparse sagebrush and cacti find a living hard. Not here alone where the blocks are so conspicuous as to invite their carrying away is a former flourishing growth of vegetation attested, but over large adjoining areas of desert search has brought the like past tenancy to light. Fragments of what once were trees have been picked up in the Little Colorado basin and in the neighborhood of Ash Fork, on both sides, that is, of the present forest crown that covers the higher part of the plateau from which rise the San Francisco Peaks. In the blue distance the mountains look down verdure-clad upon a now encircling waste, but one which in earlier eras was as pine-bearing as they. Their lofty oasis is all that is now left of a once fertile country; the retreat of the trees up the slopes in consequence of a diminishing rainfall, until a rise of two thousand feet from what once was timber-land is necessary to reach the tree-line of today, being typical of desert lands, and testifying to greater aqueous affluence in the past. In the same manner streams descend from the cedar-

clad range of the Lebanon to lose themselves in the Arabian desert just without the doors of Damascus; and Palestine has desiccated within history times. Palestine, a land once flowing with milk and honey, can hardly flow poor water now, and furnishes another straw to mark the ebbing of the water supply.

This making of deserts is not a sporadic, accidental, or local matter, although local causes have abetted or hindered it. On the contrary, it is an inevitable result of planetary evolution, a phase of that evolution which follows from what has been said in Chapter XII on the abandonment of a planet by its water. Deserts are simply another sign of the same process. The very aging which began by depriving a body of its seas takes from it later its forest and its grass. A growing scarcity of water is bound to depauperate the one, as it depletes the other. We have positive proof of the action in our own deserts. For these bear testimony, in places at least, to not having always been so, but to have gradually become so within relatively recent times. But we have more general proof of the action from the position occupied on the earth's surface by its deserts.

The significant fact about the desert-making so stealthily going on is that only certain zones of the earth's surface are affected. Those belting the two tropics of Cancer and Capricorn, for several degrees

on either side of them, most exhibit the phenomenon. Such positioning of the deserts is not due to chance. Directly, of course, desertism is due to dearth of rain. This in turn depends on the character and condition of the winds. If a wind laden with moisture travel into a colder region of the globe, its moisture is precipitated in rain and we have a fertile country; if it voyage into a warmer clime it takes up what little moisture may be there already and a desert is the result.

Now our system of winds is such as to produce a fall of rain for the different latitudes, as tabulated by Supan, thus: —

Zone I	40°N–27°N	Little rain in summer but much in winter.
II	27 N–19 N	Little rain at all seasons.
III	19 N– 7 N	Little rain in winter but much in summer.
IV	7 N– 1 N	Abundant rain at all seasons.
V	1 N–17 S	Little rain in winter but much in summer.
VI	17 S–30 S	Little rain at all seasons.
VII	30 S–35 S	Little rain in summer but much in winter.

Zones II and VI, the zones of minimum rainfall, are also those in which the deserts occur. The northern one traverses southern California, Arizona, New Mexico, the Sahara, Arabia, and the Desert of Gobi; the southern, Peru, the South African veldt, and central Australia. The belts are wavy bands which by their form betray both a general underlying trend to drought

at these parallels and also the effect of local topography in the matter.

From being distributed thus in belts, it is evident that the deserts are general globe phenomena, and from their being found only in the zones of least rainfall, that the earth has itself entered, though not far as yet, upon the desert stage of its history. Once begun, the desert areas must perforce spread as water becomes scarce, invading and occupying territory in proportion as the rainfall there grows small.

Now the axial tilt of Mars is almost exactly the same as that of our Earth, the latest determinations from the ensemble of measures giving 24° for it. Here, then, we have initial conditions reproducing those of the earth. But from the smaller size of the planet that body would age the earlier, since it would lose its internal heat the more rapidly, just as a small stone cools sooner than a larger one. On general principles, therefore, it should now be more advanced in its planetary career. In consequence, desertism should have overtaken more of its surface than has yet happened on earth, and instead of narrow belts of sterility we should expect to find there Saharas of relatively vast extent.

Now, such a state of things is precisely what the telescope reveals. The ochre tracts occupy nine tenths of the northern hemisphere and a third of the southern.

Three fifths, therefore, of the whole surface of the planet is a desert.

Of cosmic as well as of particular import is the correlation thus made evident between the physical prin-

Desert areas.

ciples that effect the aging of a planet and the aspect Mars presents. Experimental corroboration of those laws is thus afforded, while, reversely, confidence in their applicability is increased. With continued observation the planet appears more desiccate as improved conditions bring it nearer. Dry land as it

was thought to be proves even drier, something which lacks water for the ordinary necessities of a living world.

The picture the planet offers to us is thus arid beyond

Desert areas.

present analogue on Earth. Pitiless as our deserts are, they are but faint forecasts of the state of things existent on Mars at the present time. Only those who as travelers have had experience of our own Saharas can adequately picture what Mars is like and what so waterless a condition means. Only such can understand

what is implied in having the local and avoidable thus extended into the unescapable and the world-wide; and what a terrible significance for everything Martian lies in that single word: *desert.*

CHAPTER XIV

SUMMARY

IF, now, we review with the mind's eye the several features of Mars which we have surveyed with the bodily one, we shall be surprised to find to what they commit us. Suggestive as each is considered by itself, the *ensemble* into which they combine proves of multiplicate force in its implication. For each turns out to fit into place in one consistent whole, a scheme of things in which are present all the conditions necessary to the existence and continuance of those processes which constitute what we call life. In short, we are conducted with a cogency, which grows as we consider it, to the conclusion that Mars is habitable.

Two ways of appreciating this cogency are open to us. We may treat it with the simple reasoning of commonsense, as we should a dissected map or a piece of machinery in which we realize we are right when the several parts at last fit together and the picture stands revealed or the machine works. Or we may subject the evidence to quantitative estimates for and against by the doctrine of probabilities, and thus evaluate the chances of its being correct. Consciously or un-

consciously, this is what we are about in our decisions every day of our lives. At the one end of the line are those skillful judgments where the balance is so keen-edged that the least overweight on the one side dips the scales to a conclusion. At the other extremity stand those deductions which we usually speak of as proved, such as the law of gravitation. But both assurances rest really upon probability and differ only in degree. What we mean by proof of anything is that a supposition advanced to account for it explains all the facts and is not opposed to any of them, and that the balance of probability in consequence is very largely in its favor.

Now, if several pieces of evidence, distinct in their origin, concur to a given conclusion, the probability that that conclusion is correct is far greater than what results from each alone; and mounts up soon to something much exceeding what bettors at races call certainty odds. However unversed the average man may be in calculating the probability, he recognizes the fact in his dealings with his fellows by the way he attaches weight to concurrent testimony. It is such concurrent evidence that we have now to consider. To this end we will marshal the several facts ascertained in a summarized list for their easier intercomparison.

These facts are:—

(1) Mars turns on its axis in 24 h. 37 m. 22.65 s. with reference to the stars, and in 24 h. 39 m. 35.0 s. (as a

mean) with regard to the Sun. Its day, therefore, is only about forty minutes longer than ours.

(2) Its axis is tilted to the plane of its orbit by about 23° 59′ (most recent determination, 1905). This gives the planet seasons almost the counterpart of our own in character; but in length nearly double ours, for

(3) Its year consists of 687 of our days, 669 of its own.

(4) Polar caps are plainly visible which melt in the Martian summer to form again in the Martian winter, thus implying the presence of a substance deposited by cold.

(5) As the polar caps melt, they are bordered by a blue belt, which retreats with them. This excludes the possibility of their being formed of carbon dioxide, and shows that of all the substances we know the material composing them must be water.

(6) In the case of the southern cap, the blue belt has widenings in it in places. These occur where the blue-green areas bordering upon the polar cap are largest.

(7) The extensive shrinkage of the polar snows shows their quantity to be inconsiderable, and points to scanty deposition due to dearth of water.

(8) The melting takes place locally after the same general order and method, Martian year after year, both in the south cap,

(9) And in the north one. This is evidenced by the

recurrence of rifts in the same places annually in each. The water thus let loose can, therefore, be locally counted on.

(10) That the south polar cap is given to greater extremes than the north one, implies again, in view of the eccentricity of the orbit and the tilt of the axis, that deposition in both caps is light.

(11) The polar seas at the edges of the caps being temporary affairs, the water from them must be fresh.

(12) The melting of the caps on the one hand and their reforming on the other affirm the presence of water vapor in the Martian atmosphere, of whatever else that air consist.

(13) Since water vapor is present, of which the molecular weight is 18, it follows from the kinetic theory of gases that nitrogen, oxygen, and carbonic acid, of molecular weights 28, 32, and 38 respectively, are probably there, too, owing to being heavier.

(14) The limb-light bears testimony to this atmosphere.

(15) The planet's low albedo points to a density for the atmosphere very much less than our own.

(16) The apparent evidence of a twilight goes to confirm this.

(17) Permanent markings show upon the disk, proving that the surface itself is visible.

(18) Outside of the polar cap the disk is divided into

red-ochre and blue-green regions. The red-ochre stretches have the same appearance as our deserts seen from afar,

(19) And behave as such, being but little affected by change.

(20) The blue-green areas were once thought to be seas. But they cannot be such, because they change in tint according to the Martian season, and the area and amount of the lightening is not offset at the time by corresponding darkening elsewhere;

(21) Nor by any augmentation of the other polar cap or precipitation into cloud. It cannot, therefore, be due to shift of substance.

(22) Furthermore, they are all seamed by lines and spots darker than themselves which are permanent in place; so that there can be no bodies of water on the planet.

(23) On the other hand, their color, blue-green, is that of vegetation; this regularly fades out, as vegetation would, to ochre for the most part, but in places changes to a chocolate-brown.

(24) The change that comes over them is seasonal in period, as that of vegetation would be.

(25) Each hemisphere undergoes this metamorphosis in turn.

(26) That it is recurrent is again proof positive of an atmosphere.

(27) The changes are metabolic, since those in one direction are later reversed to a restoration of the original status. Anabolic as well as katabolic processes thus go on there; that is, growth as well as decay takes place. This proves them of vegetal origin.

(28) The existence of vegetation shows that carbonic acid, oxygen, and undoubtedly nitrogen, are present in the Martian atmosphere, since plants give out oxygen and take in carbonic acid.

(29) The changes in the dark areas follow upon the melting of the polar caps, not occurring until after that melting is under way;

(30) And not immediately then, but only after the lapse of a certain time.

(31) Though not seas now, from their look the dark areas suggest old sea bottoms, and when on the terminator appear as depressions (whether because really at a lower level or because of less illumination is not certain).

(32) That they are now the parts of the planet to support vegetation hints the same past office, as water would naturally drain into them. That such a metamorphosis should occur with planetary aging is in keeping with the kinetic theory of gases.

(33) Terminator observations prove conclusively that there are no mountains on Mars, but that the surface is surprisingly flat.

(34) But they do reveal clouds which are usually rare and are often, if not always, dust-storms.

(35) White spots are occasionally visible, lasting unchanged for weeks, in the tropic and temperate regions, showing that the climate is apparently cold,

(36) But at the same time proving that most of the surface has a temperature above the freezing-point.

(37) In winter the temperate zones are more or less covered by a whitish veil, which may be hoar-frost or may be cloud.

(38) A spring haze surrounds the north polar cap during the weeks that follow its most extensive melting.

(39) Otherwise the Martian sky is perfectly clear; like that of a dry and desert land.

The way in which these thirty-nine articles fit into one another to a mortised whole is striking enough at first sight, but becomes more and more impressive the more one considers it. For some are due to one kind of observation, some to another. In the taking they are unrelated; yet in the result they agree. Equally pregnant is the history of their acquisition. Most of them were detected as the outcome of observations at the opposition of 1894, and led to the theory which was published in the writer's first book on the subject. Others are the result of the five oppositions that have since occurred. These have proved entirely corroborative of the previous ones and of the theory then deduced,

and that in two distinct ways: first, by the accumulated evidence they have brought to the matter along the old lines; and, secondly, by what they have revealed in new directions. Of these thirty-nine articles of Martian scientific faith in observation or deduction, (9), (10), (21), (22), (25), (27), (28), (30), (33), (35), (36), and (38) are in whole or part new. That continued scrutiny is thus corroborative of the earlier results, both along the old and along new lines of investigation, warrants additional confidence in the conclusion.

Considering, now, these counts, we see that they make reasonably evident on Mars the presence of: —

1. Days and seasons substantially like our own;
2. An atmosphere containing water vapor, carbonic acid, and oxygen;
3. Water in great scarcity;
4. A temperature colder than ours, but above the Fahrenheit freezing-point, except in winter and in the extreme polar regions;
5. Vegetation.

First and foremost of these is air. In order to make it possible for vital processes of any sort to take place, the body of a planet must be clothed with an atmosphere, by the modesty of nature, the old astronomers would have said. Such a covering subserves two purposes: it keeps out the cold of space, thus permitting the maintenance of a temperature sufficient to support

life, and it affords a medium through which metabolism can go on.

Now the presence of air is attested first and foremost by the fact of change in the Martian markings, (12), (13), (26), (28), and (35). The changes observed are conspicuous; are both inorganic (in the case of the polar caps), (12), (13), and (35), and metabolic or organic, (26) and (28), (in the case of the blue-green areas); that is, they consist of building up as well as of pulling down and are planet-wide in occurrence. Such changes could not occur in the absence of an atmosphere. They show that this atmosphere consists of water vapor, (5), carbonic acid, and oxygen, (28).

The limb-light, the apparent evidence of a twilight arc and the planet's low albedo indicate that this atmosphere is thin. The appearance of the surface, (35), suggests cold, indicative again of a thin air. Such tenuity is in accord with what *a priori* principles would lead us to expect, and tends to show that reliance on general principles is here not misplaced, a point of some interest.

Lastly, the occurrence of clouds, (34), visibly floating and traveling over the surface, and haze at times, (38), proves in another way the existence of the medium in which alone this could be possible.

Water is the next substance vital to planetary life. As to its actual presence the polar caps, (4)–(12), have

most to say; as to its relative absence, the rest of the disk, (17)–(22). The forthright conception of the polar caps as composed of snow and ice is borne out by further investigation into what could cause the observed phenomenon. Carbonic acid, the only other substance we know capable in any way of resembling what we see, turns out not capable of producing one important detail of the caps' appearance, the blue band, (5), which accompanies them in their retreat. Water alone could do this.

The melting of the caps shows that water vapor must be a constituent of the Martian atmosphere. Moreover, as the molecular weight of water vapor is less than that of oxygen or nitrogen or carbon dioxide, if the former can exist in the atmosphere of the planet, *a fortiori* must these other gases. So that from this we have knowledge of the possibility of the presence of oxygen, nitrogen, and carbon dioxide there. From (28) we saw that their actual existence is demonstrated.

The next step is the ascertainment that the water is in very small amount. The extensive melting of the caps, (7), shows their quantity to be inconsiderable, which is the first fact pointing to a dearth of water. The second comes from the aspect and behavior of the reddish-ochre regions which proclaim them deserts, (18) and (19); the third from the detection of the character of the blue-green areas as not seas, (20), (21),

and (22). In several different ways, study of these regions asserts their non-aquatic constitution, the easiest to appreciate being that they are traversed by permanent dark lines and other equally sedentary markings, (22). No bodies of water, therefore, are to be seen outside of the ephemeral polar seas, immediately surrounding the caps as they melt.

This leads us to the third presence on Mars indicative of a living world: vegetation. The other two spoke of substances necessary to life, the premises in the case, this one of organic existence itself, its conclusion. The evidence consists of static testimony from the look of the blue-green areas, (23), and of kinematic derived from their behavior, (24), (25), (26), and (27). Vegetation would present exactly the appearance shown by them, and nothing that we know of but vegetation could. But suggestive as their appearance is, it is as nothing compared with the cogent telltale character of their behavior. The seasonal change that sweeps over them is metabolic, constructive as well as destructive, that is, and proclaims an organic constitution for them such as only vegetation could produce. In tint their metamorphoses are those of the same substance. For the blue-green lapses into ochre and revives again to blue-green just as vegetation does on our own Earth at the proper season of the year, taking both the Sun and the advent of water into the reckoning. Furthermore, certain

of the largest dark areas turn to a chocolate-brown at times, which is the color of fallow ground and suggestive, at least, as occurring where the blue-green at other seasons is the most pronounced. Lastly, the change occurs at the epoch at which, from a knowledge of the melting of the polar caps, theory demonstrates that it ought to take place if it be due to the action of vegetation.

That this was the case was evident from much less information than is forthcoming today; but what is significant, each new fact discovered about the planet goes to show that it is unquestionably true.

PART II

NON-NATURAL FEATURES

CHAPTER XV

THE CANALS

FROM the detection of the main markings that diversify the surface of Mars we now pass to a discovery of so unprecedented a character that the scientific world was at first loath to accept it. Only persistent corroboration has finally broken down distrust; and, even so, doubt of the genuineness of the phenomena still lingers in the minds of many who have not themselves seen the sight because of the inherent difficulty of the observations. For it is not one where confirmation may be summoned in the laboratory at will, but one demanding that the watcher should wait upon the sky, with more than ordinary acumen. This latter-day revelation is the discovery of the canals.

Quite unlike in look to the main features of the planet's face is this second set of markings which traverse its disk, and which the genius of Schiaparelli disclosed. Unnatural they may well be deemed; for they are not in the least what one would expect to see. They differ from the first class, not in degree, but in kind; and the kind is of a wholly unparalleled sort. While the former bear a family resemblance to those of the

earth; the latter are peculiar to Mars, finding no counterpart upon the earth at all.

Introduction to the mystery came about in this wise, and will be repeated for him who is successful in his search. When a fairly acute eyed observer sets himself to scan the telescopic disk of the planet in steady air, he will, after noting the dazzling contour of the white polar cap and the sharp outlines of the blue-green seas, of a sudden be made aware of a vision as of a thread stretched somewhere from the blue-green across the orange areas of the disk. Gone as quickly as it came, he will instinctively doubt his own eyesight, and credit to illusion what can so unaccountably disappear. Gaze as hard as he will, no power of his can recall it, when, with the same startling abruptness, the thing stands before his eyes again. Convinced, after three or four such showings, that the vision is real, he will still be left wondering what and where it was. For so short and sudden are its apparitions that the locating of it is dubiously hard. It is gone each time before he has got its bearings.

By persistent watch, however, for the best instants of definition, backed by the knowledge of what he is to see, he will find its coming more frequent, more certain and more detailed. At last some particularly propitious moment will disclose its relation to well-known points and its position be assured. First one

such thread and then another will make its presence evident; and then he will note that each always appears in place. Repetition *in situ* will convince him that these strange visitants are as real as the main markings, and are as permanent as they.

Such is the experience every observer of them has had; and success depends upon the acuteness of the observer's eye and upon the persistence with which he watches for the best moments in the steadiest air. Certain as persistence is to be rewarded at last, the difficulty inherent in the observations is ordinarily great. Not everybody can see these delicate features at first sight, even when pointed out to them; and to perceive their more minute details takes a trained as well as an acute eye, observing under the best conditions. When so viewed, however, the disk of the planet takes on a most singular appearance. It looks as if it had been cobwebbed all over. Suggestive of a spider's web seen against the grass of a spring morning, a mesh of fine reticulated lines overspreads it, which with attention proves to compass the globe from one pole to the other. The chief difference between it and a spider's work is one of size, supplemented by greater complexity, but both are joys of geometric beauty. For the lines are of individually uniform width, of exceeding tenuity, and of great length. These are the Martian canals.

Two stages in the recognition of the reality confront

the persevering plodder: first, the perception of the canals at all; and, second, the realization of their very definite character. It is wholly due to lack of suitable conditions that the true form of the Martian lines is usually missed. Given the proper prerequisites of location or of eye, and their pencil-mark peculiarity stands forth unmistakably confessed. It is only where the seeing or the sight is at fault that the canals either fail to show or appear as diffuse streaks, the latter being a halfway revelation between the reality and their not being revealed at all. Much misconception exists on this point. It has been supposed that improved atmospheric conditions simply amount to bringing the object nearer by permitting greater magnification without altering the hazy look of its detail.[1] Not so. They do much more than this. They steady the object much as if a page of print from being violently shaken should suddenly be held still. The observer would at once read what before had escaped him for being a blur. So is it with the canals. In reality, pencilings of extreme tenuity, the agitations of our own air spread them into diffuse streaks; an effect of which any one may assure himself by sufficiently rapid motion of a drawing in which they are depicted sharp and distinct, when he will see them take on the streaky look. As the writer has observed them under both aspects, and has seen

[1] M. l'abbé Moreux.

them pass from the indefinite to the defined as the seeing improved, he has had practical proof of the fact, and this not once, but an untold number of times.

Atmospheric conditions far superior to what are good enough for most astronomic observations are needed for such planetary decipherment, and the observer experienced in the subject eventually learns how all-important this is. Under these conditions the testimony of his own eyesight upon the character of these markings is definite and complete. And the first trait that then emerges from confusion is that the markings are *lines;* not simply lines in the sense that any sufficiently narrow and continuous marking may so be called, but lines in the far more precise sense in which geometry uses the term. They are furthermore straight lines. As Schiaparelli said of them: they look to have been laid down by rule and compass. The very marvel of the sight has been its own stumbling-block to recognition, joined to the difficulty of its detection. For not only is the average observatory not equipped by nature for the task, but what is not good air often masquerades as such. Trains of air waves exist at times so fine as to confuse this detail, or even to obliterate it entirely; while at the same time they leave the disk seemingly sharp-cut, with the result that one not well versed in such vagaries thinks to see well when in truth he is debarred from seeing at all. When study of the condi-

tions finally ends in putting him upon the right road, the sight that rewards him can hardly be too graphically described.

Next to the fact that they are *lines*, definiteness of direction is the chief of their characteristics to strike the observer. The lines run straight throughout their course. This is absolutely true of ninety per cent of them, and practically so of the remaining ten per cent, since the latter curve in an equally symmetric manner. Such directness has I know not what of immediate impressiveness. Quite unlike the aspect of the main markings, which show a natural irregularity of outline, these lines offer at the first glance a most unnatural regularity of look. Nothing on Earth of natural origin on such a scale bears them analogue. Nor does any other planet show the like. They are, in fact, distinctively Martian phenomena. This is the first point in which they differ from the markings we have hitherto described. The others were generic planetary features; these are specific ones, peculiar to Mars.[1]

[1] As some misrepresentation has been made on this subject through misapprehension of the writer's observations on Venus and Mercury, it may be well to state that the tenuous markings on both these other planets entirely lack the unnatural regularity distinguishing the canals of Mars. The Venusian lines are hazy, ill-defined, and non-uniform; the Mercurian broken and irregular, suggesting cracks. Neither resemble the Martian in marvelous precision, and have never been called canals by the writer nor by Schiaparelli, but solely by those who have not seen them and have misapprehended their character and look.

Equally striking is the uniform width of each line from its beginning to its end, as it stands out there upon the disk. The line varies not in size throughout its course any more than it deviates in direction. It counterfeits a telegraph wire stretched from point to point. Like the latter seen afar, the width, too, is telegraphic. For it is not so much width as want of it that is evident. Breadth is inferable solely from the fact that the line is seen at all, and relative size by difference of insistency. Indeed, the apparent breadth has been steadily contracting as the instrumental, atmospheric, and personal conditions have improved. All three of the factors have conduced to such emaceration, but the middle one the most. For the air waves spread every marking, and the effect is relatively greatest upon those which are most slender. As the currents of condensation and rarefaction pulse along, their denser and their thinner portions refract the rays on either side of their true place, and thus at the same time confuse a marking and broaden it. The consequence is that the better the atmospheric conditions and the more that has been learned about utilizing them, the finer the lines have shown themselves to be.

Herein we have a specific intrinsic difference between the fundamental features and these lines: the main markings have extension in two dimensions, the latter in one.

Distinctive as they thus are, they have, in keeping with their appearance, been given a distinctive name, that of canal. Useful as the name is and, as we shall later see, applicable, it must not be supposed that what we see are such in any simple sense. No observer of them has ever considered them canals dug like the Suez Canal or the phœnix-like Panama one. This supposition is exclusively of critic creation.

Their precise width is not precisable. They show no measurable breadth and their size, therefore, admits for certain only of an outside limit. They cannot be wider than a determinable maximum, but they may be much less than this. The sole method of estimating their width is by comparison of effect with a wire of known caliber at a known distance. For this purpose a telegraph wire was stretched against the sky at Flagstaff, and the observers, going back upon the mesa, observed and recorded its appearance as their stations grew remote. It proved surprising at what great distances a slender wire could be made out when thus projected against the sky. The wire in the experiment was but 0.0726 of an inch in diameter and yet could be seen with certainty at a distance of 1800 feet, at which point its diameter subtended only 0.69 of a second of arc. How small this quantity is may be appreciated from its taking more than ninety such lines laid side by side to make a width divisible by the eye. Such

slenderness at the then distance of Mars would correspond, under the magnification commonly used, only to three quarters of a mile. Theoretically, then, a line three quarters of a mile wide there should be visible to us. Practically, both light and definition is lost in the telescope, and it would be nearer the mark to consider in such case two miles as the limit of the perceptible. With the planet nearer than this, as is often the case, the width which could be seen would be proportionally lessened. Perhaps we shall not be far astray if we put one mile as the limiting width which could be perceived on Mars at present, with distance at its least and definition at its best.

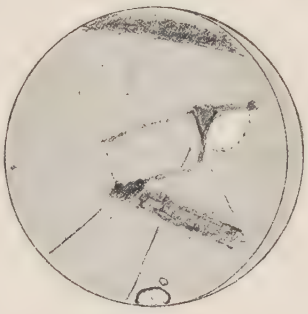
That so minute a quantity should be visible at all is due to the line having a sensible length and by summation of sensations causing to rise into consciousness what would otherwise be lost. A stimulus too feeble to produce an effect upon a single retinal rod becomes recognizable when many in a row are similarly excited.

The experiment furnished another criterion, of importance as regards the supposition that the lines on Mars are illusory. It showed that brain-begotten impressions of wires that did not exist could be told from the real thing when the wire subtended 0.69 of a second of arc or more; that below this the outside stimulus was too weak to differ recognizably from optic effects

otherwise produced; while when the real wire was diminished to 0.59″, it could not be seen at all. Now, the majority of lines on Mars so far recognized and mapped lie in strength of impression far above the superior limit of 0.69″. To one versed in Martian canal detection there is no possibility of self-deception in the case, the canals being very much more salient objects to an expert than those who have not seen them suppose. For it must not be imagined that, when one knows what to be on the lookout for, they are the difficult objects they seem to the tyro. Just as the satellites of Mars were easily seen once they were discovered, so with these lines.

A mile or two we may take, then, with safety as the smallest width for one of the lines. The greatest was got by comparing what is by far the largest canal, the Nilosyrtis, with the micrometer thread. From such determination it appeared that this canal was from 25 to 30 miles wide. But it is questionable whether the Nilosyrtis can properly be termed a canal, so much does it exceed the rest. It is certainly far larger than the majority of them. From comparative estimates between its size and that of the others, 15 to 20 miles for the width of the larger of the Martian canals seems the most probable value, and 2 or 3 miles only of the more diminutive of those so far detected.

On the other hand, the length of the canals is relatively enormous. With them 2000 miles is common; while many exceed 2500, and the Eumenides-Orcus is 3540 miles from the point where it leaves the Phœnix Lake to the point where it enters the Trivium Charontis. This means much more on Mars than it would on Earth, owing to the smaller size of the planet. Such a length exceeds a fourth of the whole circumference of its globe at the equator. But what is still more remarkable, throughout the whole of the long course taken by the canal, it swerves neither to the right nor to the left of the great circle joining the two points.



Showing the Eumenides-Orcus.

Of these several peculiarities of the individual canal it is difficult to know to which to allot the palm for oddity, — great circle directness, excessive length, want of width, or striking uniformity. Each is so anomalously unnatural as to have received the approving stamp of incredulity. Yet so much, wonderful as it is, is encountered on the very threshold of the subject.

CHAPTER XVI

THEIR SYSTEM

MUCH more stands beyond. For, outdoing in suggestiveness the individual traits of the lines, is the relation shown by them to one another. It is the communal characteristics of the phenomenon that are most surprising.

The individual peculiarities of the lines impress themselves at once; the communal, only as the result of experience, collation, and thought. As the observer becomes trained, the more lines he is able to make out, until they fairly seam the whole surface of the light areas of the planet. Their name collectively is legion; while to name them individually is fast getting, for the number detected, to be impossible. As with the increasing family of asteroids, figures alone will prove adequate to the task.

Interdependence, not independence, marks the attitude of the canals. Each not only proceeds with absolute directness from one point to another, but at its terminals it meets canals which have come there with like forthrightness from other far places upon the planet. Nor is it two only that thus come together at a common junction. Three, four, five, — up to as many as

fourteen,— thus make rendezvous, and it is a poor junction that cannot show at least six or seven. The result is a network which triangulates the surface of the planet like a geodetic survey into polygons of all shapes and sizes, the Arian areolas. The size of the pieces forming this tesselate ground depends solely upon the fineness of the definition. With every increase in the power of seeing, each areola is cut into still smaller portions, usually by connection between its corners. Thus a polygon or rhombus is split into triangles which may themselves be divided in like manner, the mosaic breaking into bits, the sides of which, however, always remain clean-cut.

From this arrangement it is at once evident that the canals are not fortuitously placed. That lines should thus meet exactly and in numbers at particular points, and only there, shows that their locating is not the outcome of chance. If very thin rods be thrown haphazard over a surface, the probability that more than two will cross at the same point is vanishingly small. Increasingly assured is it that this would not happen generally. The result we see is therefore not a matter of chance, but of some law working to that end.

To the detection of what that law is precedes the easier ascertainment of what it is not. The lines, for example, cannot be rivers, which was the first explanation offered of them by Proctor many years ago, be-

cause of their peculiar straightness. Nor can they be channels, the name given to them by Schiaparelli, except in the non-committal sense in which he used the term. For here again their geometric regularity is bar to any estuary-like hypothesis. For quite another reason they cannot be cracks, because of their uniform size throughout. Their unbroken character is another fatal objection to the same suggestion. For cracks in ground never pursue for any great distance a continuous course, any more than they keep uniform or straight. The state of an old ceiling is a case in point. When it breaks, it does so in fissures that proceed a certain way, then give out to be continued by others roughly parallel to the first, but parted from them. The same character is shown by the rills on the moon. The 'Straight Wall,' so called, is composed of three such sections, and the little rill to the right of it, west of Birt, of four.

Thus were they seen at Flagstaff, and as, to the writer's knowledge, they have not been so depicted elsewhere, the fact may serve to give some idea of the definition there.

That the underlying cause is not explosion or contraction is also evidenced by the canals collectively as well as individually, their arrangement into a system, for cracks, however produced, could only originate from certain centres and could not fit into those starting from others, as the canals invariably do. For

each canal goes as undeviatingly to one terminal as it left forthrightly from another. If one wishes to see what explosion or contraction can do, he has only to look at the moon through an opera-glass, when he will be shown a very different sight from what the drawings of Mars detail. Thus just as, considered individually, the lines cannot be watercourses because of their straightness, so they cannot be cracks because of dovetailing into one another.

The fact that they form a system shows that whatever caused them operated over the whole planet, linked in cause as in effect throughout each section. This at once negatives any purely physical cause of which we have cognizance. For upon a globe still so subject to physical vicissitude as Mars by its aspect shows itself to be, latitude must tell in the phenomena its zones exhibit. Polar snows that wax and wane speak of arctic conditions very diverse from temperate and tropic states, and what would affect the one could not influence the other. Yet the mesh rises superior to zonal solicitation as to local barrier. It is not something dependent either on the temperament or the complexion of the globe's different parts. It transcends surface restriction and becomes planet-wide in its working. The importance of this omnipresence dilates in meaning as one dwells in thought upon it.

Ubiquitous as it is, the mesh which thus covers the

Martian surface like a veil spread completely over it, is unlike a veil in being of irregular texture. Not only are the interstices of various shape and pattern, but the mesh itself is of locally differing size. Though the threads are straight and uniform throughout, they are not all alike, besides being unsymmetrically interwoven. Some are at least of ten times the coarseness of others, and from this fact and the bo-peep effect of our air waves all are not visible at once. In consequence the network is not so impressive at first glance as it becomes upon a synthesis of the observations. When this is done, the surface proves to be fairly evenly cut up, as recourse to the maps printed in this volume will amply demonstrate. These maps, as on page 31, are made from the results of but one opposition, and as at each opposition some zone is in a more canal-showing state than others, owing to the Martian season at the time, a still greater uniformity in canal distribution results from a blending of many.

From the completeness of the mesh, it follows that in the course taken severally by the canals no one direction preponderates over another. Considered by and large, the canals seem to be equally distributed round the compass points; and this at all longitudes and nearly all latitudes. Tropic, temperate, and even arctic canals show a pleasing impartiality in the matter of the course pursued. The only exceptions occur in the

neighborhood of the pole. There a slight tendency may be seen to a north and south setting.

Though so much is visible in a general way from the map, it is of interest to go into the subject with more particularity and to that end to show it statistically. The several canals traversing each zone were therefore counted, and the area of the zone computed. The manner of canal distribution thus found is given in the following table, in the second column of which stand the areas of the several zones upon the planet, each ten degrees wide, except the one next the snow, and in the third the number of canals found traversing them, reduced to percentages of the 0°–10° zone. A fourth column shows the total length of the canals in each zone, those from 0° to 20° being taken from the 1896 globe, those from 20° to 90° from the 1903. This is in order to annul the effect of the seasons upon the showing of the canals as much as possible.

Zone	Area	No. of Canals Wtd.	Actual Length
0°–10°	1.00	1.00	1.00
10°–20°	.97	.89	.91
20°–30°	.91	.93	.72
30°–40°	.82	.90	.71
40°–50°	.71	.78	.66
50°–60°	.58	.64	.59
60°–70°	.42	.43	.42
70°–80°	.26	.30	.34
80°–85°	.07	.12	.11

The numbers continue fairly non-committal until we begin to approach the pole, when they commence to increase. Much the same result is got if we take the actual canal-lengths in each zone, as the fourth column shows. The crowding of the canals poleward is marked. The canals, therefore, are phenomena that stand in peculiar relationship to the polar cap. This corroborates the inference about them due to their running out of the edge of the snow. They not only emanate from it, but they do so in numbers surpassing what is elsewhere observable over the disk.

Otherwise is it with their departure-points. These are not scattered haphazard over the surface, but bear to its general features definite relations. If we consider the map, obliterating the lines, and then seek to connect the most salient points of the planet's topography by direct avenues of communication, we shall find that our putative lines fall exactly where the real ones occur. For the most part, the real lines emanate from well-marked indentations in the dark regions, fitted by natural position for departure-points, what, if these were seas, we should call their most conspicuous bays. They thus leave in the southern hemisphere the deeper folds of the great diaphragm, for the most part; though on occasion they run out of them where they will. From equally conspicuous points in the dark northern areas other lines proceed; while in the centre of the

continents, the canals make for more or less salient spots, small patches of shading like the Trivium or the Wedge of Casius, or simply round black radiants, like the Luci Ismenii.

From this it appears that the lines are locally dependent upon the general topography of the fundamental features of the surface. For some reason they connect the very points most suggestive of intercommunication. As from their characteristics it is perfectly evident that the lines are neither rivers nor cracks, it follows that such a communicating habit is of the most telltale character. To be so dissimilar in kind from the main markings and yet so dependent upon them, hints that their positioning occurred after the formation of the main features themselves. We reach thus from the look of the lines and their location a most striking deduction, that the lines are not coeval with the main markings, but have come into being later and with reference to the general topography of the planet. The network is not only a mesh *de facto*, then, but one *de jure*, which, subsequent to the fashioning of the seas and continents and what these have now become, has been superposed upon them.

CHAPTER XVII

GEMINATION OF THE CANALS

FRAUGHT with more difficulty than the detection of the lines alone is the next discovery made upon the disk: the recognition of pairs of lines traversing it.

In 1879, while Schiaparelli was engaged in scrutinizing the strange *canali* he had discovered on the planet the opposition before, he was suddenly surprised to mark one of them double. Two closely parallel lines confronted him where but a single one had previously stood. So unaccountable did the sight seem, that he hesitated to credit what he saw, being minded to attribute the vision to illusion of some sort and the more so that it was not renewed. While he was still wondering what it meant, the planet parted company with the Earth, carrying its enigma with it.

When the two bodies again drew near to one another in 1882, Schiaparelli set himself to watch for a recurrence of the strange phenomenon. Before long it came, and more bewilderingly than at first; for not one canal alone, but a score of them now showed in duplicate, each presenting to his astonished gaze twin lines per-

fectly matched and preserving throughout their distance apart. Suspecting diplopia or some other optical trick, he tried various eyepieces to a test of the cause but to no change in the effect. The twin lines continued visible, do what he would, insisting on their own reality in spite of all solicitation to merge. How cautious he was in the matter, and how unwilling at first to believe the evidence of his eyes, is shown by the care he took to guard against deception. It was not until he had assured himself of the reality of the phenomena that he believed what he had seen.

It so chanced that my first experience of the thing was almost equally startling, so unexpected was it and so exceedingly sharp was the definition at the time. It was in an autumn early twilight, through air almost perfectly still, as the light went out of the sky and the markings on the planet began to come forth that the Phison of a sudden showed in duplicate to me, clear-cut upon the disk, its twin lines like the rails of a railway track traversing Aeria. Not more vivid do those of our transcontinental tracks appear as one sees them stretching off into the distance upon our Western plains. More impressive was the sight from the fact that I was not looking for it. It simply suddenly stood forth, this strange parallelism of pencil lines. My surprise matched the wonder of the sight.

Since then I have witnessed it several hundred times,

but never with more absolute certainty than at that first fortunate revelation. To this distinctness is due the amazement it then aroused. Not simply because of its surpassing novelty, but for the insistence with which it proclaimed itself was the effect to be ascribed. Less well seen, doubt had robbed it of its full surprise. It requires as a rule steady definition for its initial unmistakable showing, if one would be instantly convinced. Except for such it is not usually easy to the unpracticed, though often discernible to the expert after it has once been seen. But that it is real no one who had had a good view of the sight could doubt; still less after the experience had been repeated over and over again.

What appears to take place is this: where previously a single pencil-like line joined two well-known points upon the disk, twin lines, the one the replica of the other, stand forth in its stead. The two lines of the pair are but a short distance apart, are of the same size, of the same length, and absolutely equidistant throughout their course. It is as if a second line had in some way been mysteriously added to the first since the latter was last seen some weeks before. This in a word is the phenomenon, technically called the gemination of the canals, which has since its discovery called forth so much comment. It is not in reality quite as simple or as sudden as it seems, but this was the way in which

the phenomenon was first seen and in which it still continues to be criticised.

Self-assertive of reality, the double lines are patently objective to him who is fortunate enough to see them well. Nevertheless the great difficulty of detecting them, and the still greater difficulty of conceiving how such things can be, has led many not versed in the subject to disbelieve and from that to attempt to explain the sight as illusory. Scepticism seeks self-justification; what is hard of acceptance for its strangeness begetting hypotheses of committed error which find easy credence for their comforting conservatism. Several such have in consequence been propounded to account for the double canals. There is the diplopic theory which credits them to non-focusing; the interferential theory which would make them optical products of the telescope; and the illusion theory which would have them quite simply imaginary.

Inasmuch as in any research the assurance that a phenomenon is real is the first point about it to be established, it is a scientist's duty, not only to scan the phenomena with jealous care to that end, but to scrutinize every theory which would seek otherwise to account for them — the testing such being only second in importance to observing the things themselves. Accordingly I have examined each of the optical theories that have been advanced and critically compared

what they assert and require with the results of observation. The outcome of this research has proved as negativing to any other origin for the double canals than reality as direct observations at the telescope are positive on the point. To show this I shall review each in its consequences, confronting it with what the telescope has to say on the subject; for it is of the pith of the matter that the reality should be as demonstrable on demand as on sight. Furthermore, I shall do this before embarking on the general account of these strange things, because it is vital to any interest that one should be assured from the start of the truth of what he is to read. The preface may seem to him abstruse and prosy, but it will introduce him to some curious optical properties and will eventually enhance his concern by proving to him that what reads like fiction is all the more wonderful for being fact.

I. The Diplopic Theory

Diplopia is the property of seeing double with one eye. Surprising as it sounds it is an effect not unknown to students of optics, though it usually requires training to produce. It is possible only when the eye is not focused on the object, and is not always possible then. From my experiments its feasibility seems to depend upon whether the focus be beyond or before what it should be. If the eye be focused for a point beyond the

object, the object is doubled, if for a point this side of it, the latter is simply blurred. When the double is formed, the amount of the separation of the two images is a function of the distance the focus is out. The greater the discrepancy, the wider apart is the ensuing double. Nor does the image, of a line, for example, stop at doubling. After a certain breadth of separation is reached a third line appears, bisecting the interval between the other two. With yet greater widening the third line itself splits into a pair and so the resolution goes on. In my own experiments I have gone so far as to suspect a fifth line. Far from being unconscious, the process of producing the phenomenon is, with some people, of difficult accomplishment. Mr. Lampland, for instance, of the Flagstaff Observatory, to whom we owe the first photographing of the canals, and who sees the doubles of Mars without difficulty, has hitherto found diplopic vision an impossible feat. Even with the most practiced diplopia is never unconscious except when the object viewed, as a micrometer wire, has nothing to locate it in space. Now, the diplopic theory of the double canals supposes that in all cases the eye of the observer is thus unconsciously out of focus.

To this method of their manufacture the telescopic phenomena prove unamenable on five counts.

1. Focusing the eye on an object is now a reflex ac-

tion, so automatic has it become; in consequence one is commonly directly conscious when an object is not in focus, always so when the object presents detail. Were such not the case we should never, except by chance, see anything defined. Observing through a telescope, after a modicum of practice, differs in no respect from observing in everyday life. Consequently, that an experienced observer should not know his business in so primary a matter is preposterous. One may or may not believe that "the undevout astronomer is mad," but that the perpetually unfocused one would be is beyond debate.

2. Generically unlikely, the failure to focus is here specifically out of the question. For the observer does not use the canals to focus on for the simple reason that he cannot. Like all delicate detail, the doubles appear not continuously but by flashes of revelation, according as the atmospheric waves permit of passage undisturbed. To focus on them would be next to impossible even were it resorted to — which it never is. By the exponents of the theory this important fact is overlooked: the unforeseen showing of the canals and therefore the absolute lack of complicity of the eye in the matter. What one focuses on is the look of the main markings of the disk. Now, to suppose an observer systematically out in his perceptions of so featureful a planet as that of Mars, so that he does not know when

he sees its image sharp, implies a lack of knowledge of astronomic observation in the supposer.

3. Study by the writer shows the width of a given double canal to be constant for a given date. Within the errors of perception or recording the twin lines are always at the same epoch the same distance apart. The greater the number of determinations made, the nearer the result approaches to this mean; and the greater the care used in delineation, the less each value departs from it.

Now, if the thing were a matter of mistaken focusing, an eye could not be thus true to its own mistakes. If it were out in its focus by a certain amount at one time, it would be likely to be out by a different amount at another. So that by the very terms of its making a diplopic double would be sure to vary. Indeed, in laboratory experiments it is impossible to prevent it. For the eye rests itself automatically by change of focus, and if it be not consciously kept awry it reverts as near to the true focus as it can of its own accord.

4. Diplopia might be a respecter of persons, but it certainly could not be one of canals. For a given observer it must be objectively general in its application to the same class of objects. Consequently, if the doubling were diplopic, all canals inclined at the same angle to the vertical — for the tilt might affect the result were the eye astigmatic — should be similarly affected.

Parallel canals should parallel each other's action. With the Martian doubles this is not the case. Of two canals similarly inclined the one will be double, the other not, at the same instant and under conditions that are alike. And this persistently. For gemination is an attribute of certain canals and never of others. At a given season of the Martian year, some canals are regularly double, some invariably single. Night after night and presentation after presentation these idiosyncrasies are preserved: the doubles, always pairs, the single, always alone. Nor does the strength of the line affect the action. The single canals are some of them stronger, some of them weaker, than the doubles seen at the same time.

5. If of diplopic origin the mean width of all the doubles should be the same. For though the diplopic width would vary for a given canal according to the moment, a sufficient number of views would yield a mean width which would be the same for all. Tilt apart, the mean width of one canal would be that of another. Among Martian doubles, on the contrary, I have found the width to be a specific property of the particular canal. Each has its own mean width regardless of inclination, and this individual width differs as between one and another by as much as five to two, or, if we consider such canals as the Nilokeras I and II, by more than ten to two.

Any one of these five points is fatal to the theory; *a fortiori* all.

II. The Interference Theory

From the wave propagation of light it follows that the image of a bright line made by a lens is not itself a simple bright line but a bright band flanked by alternate dark and bright ones. It has, therefore, been suggested that a bright medial line is here concerned and that the double canal is the first of its dark pair of outriders. But the suggestion does not bear scrutiny.

1. It presupposes a central streak brighter than the rest of the disk to give birth to the twin dark lines. This should itself be visible in the image; but no such bright backbone is seen.

2. It demands a perfectly definite width of separation for a given aperture — which is not that observed.

3. It makes the width a function of the aperture, decreasing as this increases — which is not sustained by observation. Different apertures produce no effect on the widths of the Martian doubles, as the writer has shown (Lowell Observatory Bulletin, No. 5) by a change of aperture from twenty-four to six inches.

4. Under like optical conditions the optically produced doubles would be all of a width; while the Martian ones show idiosyncratic widths, each peculiar to itself.

III. The Illusion Theory

Known also as the Small Boy Theory from the ingenuous simplicity on which it rests, this theory attacks the reality of the doubles by questioning that of the canals *en bloc*. Because some boys from the Greenwich (Reform or) Charity School, set to copy a canal-expurgated picture of the planet, themselves supplied the lines which had preceptorily been left out, the Martian canals have been denied existence; which is like saying that because a man may see stars without scanning the heavens, therefore those in the sky do not exist. As to the instructions the boys received we are left in the dark. It looks as if some leading questions had unconsciously been put to them. At all events, English charity boys would seem to be particularly pliant to such imagination, for when Flammarion retried the experiment with French schoolboys, and even inserted spaced dots for the canals in the copy, not a boy of them drew an illusory line.

The fact is, this is one of those deceptive half-truths which is so much more deleterious than an unmitigated mistake. Under certain circumstances it is quite possible to perceive illusory lines, due either to shadings otherwise unmarked and thus synthesized or to immediately precedent retinal impressions transferred to places where they do not belong by rapid motion

of the eye, as I had myself discovered before the English experiment had been tried. But, as I have also found out, these effects are produced only at the limit of vision, and in that limbo of uncertainty the whole art of the observer consists in learning to distinguish the true from the false. Strength of impression, renewed effect *in situ*, and a peculiar sense of reality or the reverse enable him to adjudge the two. More experience than the boys possessed would have helped them to part the sheep from the goats. But, furthermore, and fatally to the theory here in question, the Martian canals when well seen are not at the limit of vision as its framers supposed, but well within that boundary of doubt; so that the premise upon which the whole theory rests gives way. Under good atmospheric conditions the canals are comparable for conspicuousness to many of the well-recognized Fraunhofer lines and are just as certainly there.

Thus each attempt to prove the doubles non-objective turns out when specifically examined to be inconsistent with the facts. With the assurance of their reality thus made doubly sure, we pass to consideration of the things themselves.

CHAPTER XVIII

THE DOUBLE CANALS

I

RIGHTLY viewed, no more subtle tribute could be paid to the remarkable character of the phenomenon of gemination than the scepticism with which it was immediately received and which it still continues to elicit. That the sight should be regarded as illusory speaks for its surpassing strangeness; and so far as oddity goes the encomium is certainly deserved. Of the bizarre features of this curiously marked disk, the double canals were at the time of their discovery the culmination, and though things stranger still if possible have since been seen there, it is not wonderful that doubt should still incredulously stare. If the mere account of them reads like romance, to see them is an experience.

Nothing astronomical that I have ever seen has been so startlingly impressive as my first view of a double canal. Even in narration the thing justifies its effect. For a double canal consists of a pair of twin dark filaments, perfectly parallel throughout their course and inclosing between them ground of the same ochreish

cast as that which lies without. Only on occasion is this tint of their midway departed from, and then only toward a darkening, never toward a lightening of it. Except for appearing paired, the lines resemble precisely the usual single canals. In length they vary from a few hundred to a few thousand miles, while in width each component, for narrowness, hardly permits of definite ascription.

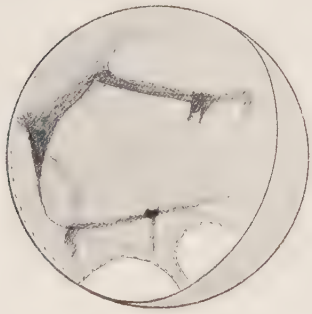
Compared for strength with the usual canal the lines of a double seem to hold on the average an intermediate position between the larger and the smaller of the single canals so far detected. Owing, however, to the massed effect of the pair by reason of their closeness, they have an advantage in showing over the singles of two to one. And this renders them among the most conspicuous and important meshes of the canal network.

Like the single canals, they vary in strength with the Martian time of year; at certain seasons developing into heavy pencil lines and at others fading away to the merest gossamers, only just discernible like cobwebs stretched across the face of the planet.

Although the individual constituent lines vary in aspect and never rise at their most to cognizable breadth, the distance parting their centres, or the width of the double, is quite measurable. The only difficulty in the way of its determination lies in the absence of a procurable unit small enough to mete it. The usual

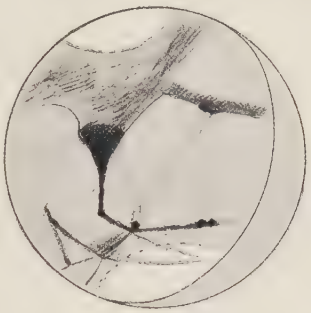
spider-threads of the micrometer are colossal in comparison with these filaments and present a standard only analogic at best. Nevertheless, by means of the finest threads that could be got, estimates of the distance between the pairs were made at Flagstaff in 1905, and the results agree as closely as the means permit with those got by measurement of the doubles as depicted in the drawings.

Of what they look like, the following illustrations give a fair idea, only that instead of being more geometrically regular in the drawing than in reality the fact is the other way. Free-hand draftsmanship at the telescope is incapable of rendering their ruled effect. No railway metals could be laid down with more precision. As to their size, the following figures derived from a typical double canal, the Phison, give some conception. This great artery of intercommunication between the Sabaeus Sinus and the Nilosyrtis is, roughly speaking, 2250 miles long; the distance between the centres of the two constituents is about 130 miles, and each line is perhaps 20 miles in breadth, when at its maximum strength. The pair follow, apparently, the arc of a great circle from



Martian doubles.

the Portus Sigaeus on the Mare Icarium to the Pseboas Lucus in latitude 40° north. The Portus Sigaeus consists of two little nicks in the coastline, looking like the carets one makes in checking off items down a list, if the space between the down and up strokes were then filled in; the Pseboas Lucus, on the other hand, is a large round dot like a small ink spot. To these two differently appearing spots, the twin lines of the Phison behave differently. While each line leaves centrally its own caret of the Portus Sigaeus at the south, at the north each touches peripherally the Pseboas Lucus, on the east and west sides respectively, the two thus just holding the Lucus between them. In position the lines are invariable, though in visibility not. Sometimes only one is seen, sometimes both show faintly, and sometimes both are conspicuously strong. The delicacy of the observations by which this detail was established is second only to its importance. It destroys at a stroke all possibility of diplopic unreality, since were that the fact the Pseboas Lucus should be doubled, which it is not. At the same time it opens vistas into the true construction of the



Martian doubles (corroborating the above).

things themselves, at present more suggestive than satisfactory.

In the great circle character of its course the Phison is quite normal. The majority of the double canals pursue the like method, running straight over the surface from one point to another, the constituents remaining equidistant throughout. But such forthrightness of direction, though the rule, is not without exceptions. The Thoth-Nepenthes, for example, sweeps round in a seemingly continuous curve to the west-southwest from the Aquae Calidae to the Lucus Moeris like some mighty bow perpetually bent. Nevertheless its lines are no less careful for all their curving to keep their distance from one end to the other of their course. The quality of being paired rises superior to change of direction.

II

Now, the first point to be noticed about the doubles is that bilateralism, or the quality of being double, is not a universal trait of the canals, either actually or potentially; it is not even a general one. Out of the four hundred canals seen at Flagstaff, only fifty-one have at any time displayed the quality; that is, one eighth roughly of the whole number observed. This point is most important; for the fact is of itself enough to disprove any optical origin for the phenomenon. The characteristic of doubling so confidently ascribed

by those who have not seen it to general optical or ocular principles proves thus the exception, not the rule, with the canals, and by so doing disowns the applicability of any merely optical solution. We shall encounter many more equally prohibitive bars to illusory explanation before we have done with the doubles, but it is interesting to meet one in this manner at the very threshold of the subject.

On the other hand, the characteristic when possessed is persistent in the particular canal, *in posse* if not *in esse*. Once shown by a canal, that canal may confidently be looked to at a proper time to disclose it again. In short, bilateralism, or the state of being dual, is an inherent attribute of the individual canal, as idiosyncratic to it as position and size.

The catalogue of canals possessing this property, so far as they have been detected at Flagstaff to date, number fifty-one if we include in the list wide parallels like the Nilokeras I and II. Eight of these were observed in 1894; nineteen more were added in 1896, making twenty-seven; in 1901 the total was raised to thirty; in 1903 to forty-eight; and in 1905 to fifty-one. Arranged by years they are tabulated below, where the numeral to the left registers for each its first recording and the position held by it in the list. The starred canals much exceed the others in width, and possibly denote a different phenomenon.

Date	Confused
1894	
1. Ganges	
2. Nectar	
3. Euphrates	
4. *Nilokeras I and II	
5. Phison	
6. Asopus	
7. Jamuna	
8. Typhon	
1896–7	
Ganges	Typhon
Euphrates	Avernus S.
Phison	
9. Lethes	
Jamuna	
10. Dis S.	
11. Titan	
12. Laestrygon	
13. Tartarus	
14. Cocytus	
15. Sitacus	
16. Amenthes	
17. Adamas	
18. Cerberus N.	
19. Cerberus S.	
20. Cyclops	
21. Gelbes	
22. Erebus	
23. Avernus N.	
24. Gigas	
25. Alander	
26. Gihon	
27. Hiddekel	

Date	Confused
1900–1	
Phison	Dis S.
Euphrates	Boreas
Hiddekel	Cerberus S.
Amenthes	Jamuna
Cerberus N.	Pyramus
Cyclops	Laestrygon
Ganges	
28. Deuteronilus	
Sitacus	
Adamas	
29. Djihoun	
Gihon	
30. Is	
1903	
Djihoun	Typhon
Hiddekel	Orontes
Phison	
Euphrates	
31. Protonilus	
Gihon	
32. Marsias	
Amenthes	
Laestrygon	
Cyclops	
Gigas	
*Nilokeras I and II	
Ganges	
Deuteronilus	
33. Pierius	
34. Callirrhoe	
Jamuna	
Sitacus	

Date	Confused	Date	Confused
1903		**1905**	
35. Astaboras S.		Amenthes	
36. Nar		Vexillum	
37. Chaos		Astaboras S.	
38. Aethiops		Adamas	
39. Hyblaeus		Cyclops	
40. Eunostos		Cerberus S.	
41. Thoth		Cerberus N.	
42. Nepenthes		Tartarus	
43. Triton		49. *Propontis	
44. Pyramus		Gigas	
45. Fretum Anian		Gihon	
46. Vexillum		Nepenthes	
Lethes		Thoth	
Cerberus S.		Laestrygon	
47. Nilokeras I		50. Polyphemus	
Cerberus N.		Deuteronilus	
48. Tithonius		Triton	
		Eunostos	
1905		Tithonius	
Nilokeras	Ganges	Callirrhoe	
Hiddekel	Chrysorrhoas	Pyramus	
Djihoun		Nar	
Sitacus		Protonilus	
Phison		51. Naarmalcha	
Euphrates			

In spite of possessing the property of pairing, a canal may not always exhibit it. To the production of the phenomenon the proper time is as essential as the property itself. So far as a primary scanning or first approximation is capable of revealing, a canal will be single at one Martian season and double at another.

Thus these canals alternated in their state to Schiaparelli and for the earlier of his own observed oppositions to the writer. In consequence Schiaparelli deemed gemination a process which the canal periodically underwent. Three stages in the development were to him distinguishable: the single aspect, a short confused aspect, and the clearly dual one.

In the single state the canal remained most of the time. It then underwent a chrysalid stage of confusion to emerge of a sudden into a perfect pair. Furthermore, he noted the times at which the pairing took place, to the formulating of a law in the case — derived from the observations of more than one opposition. His law was that the gemination occurred, on the average, three months (ours) after the summer solstice of the northern hemisphere, lasted four to five months, then faded out to begin afresh one month after the vernal equinox of the same hemisphere and continue for four months more. Expressed in Martian seasonal chronology, the periods would be about half as long. At certain times then the most pronounced specimens of doubles showed obstinately single, while the periodic metamorphosis that transformed them into duplicates was timed to the changes of the planet's year. Gemination, then, was a seasonal phenomenon.

Advance in our knowledge of the phenomenon since Schiaparelli's time, while still showing the thing to be

of seasonal habit, has changed our conception of it. It now appears that in some cases certainly, and possibly in all, the dual aspect is not a temporary condition, but the differing pronouncement of a permanent state, the fact of gemination so called being confined to a filling out of what is always skeletonly there. As the canals have come to be better seen, the three stages of existence have in some cases become recognizable as only different degrees in discernment of an essential double condition; the single appearance being due to the relative feebleness of one of the constituents and the confused showing to the weakness of both, which are then the more easily blurred by the air waves. In certain canals the last few oppositions, 1901, 1903, and 1905, have disclosed this unmistakably to be the case, as with the Phison and Euphrates, for example. With them the double character has been continuously visible, appearing not only when by Schiaparelli's law it should, but at the times when it should not; only on these latter occasions it was harder to see, whence the reason it was previously missed. So that further scrutiny, while in no sense discrediting the earlier observations, has extended to them some modification, and disclosed the underlying truth to be the varying visibility, the thing itself, except for strength in part or whole, persisting the same. Improvement in definition has lowered the see-level to revelation of continuous presence of the

dual state. It is only on occasion that the improvement is sufficient for the thing when at its feeblest to loom thus above the horizon of certainty; yet at such moments of a rise in the seeing it is enough to allow it to be glimpsed. Thus it fared with the Adamas at the opposition of 1903, with the Gigas, and with many another in years gone by. Separation has come with training and generally in the case of the wider doubles, which leads one to infer that ease of resolution is largely responsible for assurance of the permanency of the dual state. Perplexing exceptions, however, remain, so that it is possible at present only to predicate the principal of most of the double canals but not of all. Leaving the exceptions out of account for the moment, we pass to those general characteristics which are intimately linked with what has just been said.

Inasmuch as the act of getting into a state antedates the fact of being there, it is logical to let the description of the first precede. An account of the process of gemination may thus suitably come before that of its result.

Flux, affecting the double canals in whole or part, is the cause of the apparent gemination. According as the flux is partitive or total is a single or a dual state produced. At the depth of its inconspicuousness the canal may cease to be visible at all; this occurs when both lines fade out. On the other hand, the one line may outfade the other, and we are presented with a

seemingly single canal, at this its minimum showing. In such seasons of debility the one line may appear and the other not, or occasionally the other show and the one not, according to the air waves of the moment. It is at these times that the double simulates a single canal, and unless well seen and carefully watched might easily masquerade successfully as such. The Hiddekel in the depth of its dead season is peculiarly given to this alternately partitive presentation. As the flux comes on, one or both lines feel it. If one only we are likely to have a confused canal; if both, a difficult double. The strength of the lines increases until at last both attain their maximum, and the canal stands revealed an unmistakable pair, the two lines paralleling one another in appearance as in position.

At the canal's maximum and minimum the equality of its two constituents is chiefly to be remarked, though it occurs on other occasions as well. But, what is significant, when the two differ it is always the same one that outdoes its fellow. It may be the right-hand twin in one pair, the left-hand one in another; but whichever it be, for the particular canal its preëminence is invariable. It is this canal which, except for adventitious help or hindrance from the air-waves, alone shows when the double assumes the seemingly single state. We may therefore call it the original canal, the other being dubbed the duplicate. In some cases it has been

possible to decide which is which. It might seem at first sight as if this point should always be ascertainable. But the determination is more dilemmic than appears, not from any difficulty in seeing the canal, but from the absence of distinguishing earmark at its end. In a long stretch of commonplace coast, the precise point of embouchure of a solitary canal cannot be so certainly fixed as to be decisive later between two which show close together in the same locality. It is only where some landmark points the canal's terminal that the problem admits of definite solution. This telltale tag may be a bay like the Margaritifer Sinus, or double gulfs like the Sabaeus Sinus, or portions of a marking not too large to permit of partitive location like the Mare Acidalium, or a canal connection like the Tacazze which prolongs the one line and not the other. In these and similar instances the two lines become capable of identification, and in such manner have been found those comprised in the following list:—

Double Canal	Original Line	Date of Ascertainment
Phison	The Eastern	1894
Euphrates	The Western	1894
Titan	The Western	1896
Hiddekel	The Eastern	1896
Gihon	The Western	1896
Gigas	The Northwestern	1896
Djihoun	The Western	1901
Laestrygon	The Eastern	1903
Nilokeras I and II	The Northern	1903
Astaboras	The Southern	1903
Jamuna	The Eastern	1905
Ganges	The Western	1905

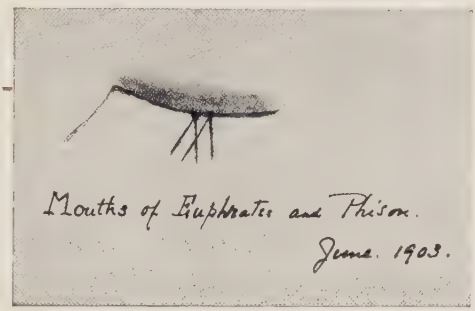
In this list of originals the canals stand chronologically marshaled according to date of detection. The Phison and Euphrates were the first to permit of intertwin identification in 1894, while the Jamuna and Ganges were the last to be added to the column in 1905. The list is not long, though the time taken to compile it was. In the case of the Ganges and the Jamuna, for example, although suspected for some time on theoretic grounds, it was only at the opposition just passed that the fact was observationally established. In his *Memoria* V, Schiaparelli has a list of similar detection, and if the present list be compared with his, the two having been independently made, the concordance of the result will prove striking, corroborative as it is of both. For the necessary observations are very difficult.

Having thus realized the original by means of its superior showing, and then identified it by its position, it is suggestive to discover that the duplicate betrays its subordinate character, not only by its relative insignificance, but by its secondary position as well. The original always takes its departure from some well-marked bay, seemingly designated by nature as a departure-point, or from a caret belonging clearly to itself; the adjunct, on the other hand, leaves from some neighboring undistinguished spot, as in the case of the additional Djihoun, or makes use of a neighbor's caret, as in

the case of the second Phison and the supplementary Euphrates. In either case it plays something of the part of an afterthought; and yet the postscript when finished reads as an integral part of the letter. An example will serve to make the connection evident while leaving the character of the connection as cryptic as ever.

In the long stretch of Aerial coastline bounding the Mare Icarium, which sweeps with the curve of a foretime beach from the Hammonis Cornu to the tip of the Edom Promontory, there stand halfway down its far-away seeming sea-front two little nicks or indentations. Even in poor seeing they serve to darken this part of the coast while in good definition they come out as miniature caret-like bays. They are the Portus Sigaei, and mark the spots where the Phison and the Euphrates respectively leave the coast. About four degrees apart, the eastern makes embouchure to the original Phison, the western to the original Euphrates, and each in some mysterious manner is associated not only in position but in action with the canal itself. In the single state each canal leaves the Mare from this its own caret, the Phison proceeding thence northeast down the disk, the Euphrates nearly due north, so that starting four degrees apart at the south they are forty degrees asunder at their northern termini. Clearly at these latter points they are not even neigh-

bors, and except for the accident of close approach at their other ends have nothing in common anywhere. And yet when gemination takes place a curious thing occurs: each borrows its neighbor's terminal as departure-point for its own duplicate canal. Having thus got its base the replica proceeds to parallel its own original canal without the least reference to the other canal whose own caret it has so cuckoo-wise appropriated. What the Phison thus does to the Euphrates, the Euphrates returns the compliment by doing to the Phison. In this manner is produced an interrelation which suggests, without necessarily being, an original community of interest; suggests it on its face and yet appears to be rather of the nature of an adaptation to subsequent purposes of a something aboriginally there.



That such latter-day appropriation is the fact is clearly hinted by the behavior of another understudy of an original canal, in this case the duplicate of the Djihoun, which in consequence of the position of its original finds no neighboring embouchure already convenient to its use. The single or original Djihoun

leaves the tip of the needle-pointed Margaritifer Sinus, which serves a like end to the Oxus and the Indus, both single canals. The Sinus is itself a single bay, and so large that for many degrees its shores on both sides converge smoothly to their sharp apex. Because of this probably, the coast in the immediate neighborhood is without canal connection, no canal being known along either side till one reaches the Hydraotes at the Aromaticum Promontorium, which marks the western limit of the gulf. The consequence is that when the Djihoun doubles, the duplicate canal, not having any terminus ready to its hand, has to make one for itself by simply running into the Margaritifer Sinus, some distance up its eastern side. It thus advertises its adjunctival character, and at the same time the general fact that a neighbor's terminus, though used from preference, when convenient, is not an essential in the process. Gemination occurs of its own initiative, but is conditioned by convenience.

Whether one canal shows thus to the exclusion of the other, or whether both stand so confused as not to be told apart, the fact remains that the double is not always recognizable as such. If we turn to the list of the doubles on page 222, we shall note that the same canals were not always seen in the dual condition at successive oppositions. Some, indeed, are so emphatically of the habit as to appear year after year in a paired state, but

others are not so constant to their possibilities. Now, when it is remembered that at different oppositions we view Mars at diverse seasons of its tropical year, we see that this means that the phenomenon is seasonal; and furthermore that its exhibition depends upon the canal's position. Gemination, like the showing or non-showing of the single canal, is conditioned by the place of the canal upon the planet.

III

Turning from such generic characteristics to more specific traits, the first thing to strike an attentive observer is that the doubles differ in width; that they are not mensurably alike in the property they hold in common of being paired. In some the twin lines are obviously farther apart than in others, and the relation persists however repeated the observations. Of two doubles the one will always surpass its fellow. This contrasted individuality first struck me in the Phison and the Euphrates; and from the first moment at which these doubles showed as such. The Phison pair seemed perceptibly the narrower of the two. A like distinction was evident at the next opposition and the next; in fact, at every succeeding one to the present day. Nor was the recognition of the fact confined to me. If we turn to Schiaparelli's Memoriae we shall find that that master had registered the same

idiomatic width for the two canals from first to last throughout his long series of records. The observation thus made proved to apply to each and all of these curious twins.

Diversity in width for different doubles appears plainly in drawings where more than one double is depicted. As an example, two drawings are here given in the text, made, the one on July 13, 1905, λ15°, and the other on July 20, λ313°. In them the Phison, Euphrates, Djihoun, and Thoth appear contrasted as unmistakably as either of them does with the single canals apparent at the same time. That this drawing is typical is borne out by all the best measures of the several doubles as seen at successive oppositions, and marshaled in the subjoined list. How truly individual the quality is stands proved by the relative values in different years which are even more accordant than the absolute ones.

The canals were :—

	Width		
	1903	1905	Mean
1. Phison	3.5	3.4	3.4
2. Euphrates	4.0	4.2	4.1
3. *Protonilus	2.8	2.0	2.4
4. Deuteronilus	2.2	2.4	2.3

* Poor.

	Width		
	1903	1905	Mean
5. Pierius	2.5	—	2.5
6. Callirrhoe	2.5	*2.1	2.3
7. *Hiddekel	3.8	4.9	4.3
8. *Gihon	3.9	4.9	4.4
9. Djihoun	2.0	1.9	1.9
10. Sitacus	3.8	*3.3	3.6
11. Jamuna	4.5	—	4.5
12. Ganges	5.0	5.2	5.1
13. Nilokeras I and II	11.0	11.7	11.3
14. Nilokeras I	2.3		2.3
15. Gigas	3.5	—	3.5
16. Laestrygon	2.2	—	2.2
17. Cerberus N.	4.0	—	4.0
18. Cerberus S.	4.0	—	4.0
19. Cyclops	2.9	*2.2	2.6
20. Nar	2.6	2.0	2.3
21. Fretum Anian	2.8		2.8
22. Aethiops	3.3	—	3.3
23. Eunostos	2.8	—	2.8
24. Lethes	2.9	—	2.9
25. Marsias	3.2	—	3.2
26. Hyblaeus	3.0	—	3.0
27. Amenthes	3.2	3.5	3.3
28. Thoth	2.8	2.3	2.5
29. Nepenthes	2.8	2.3	2.5
30. Triton	2.7	*2.3	2.5
31. Pyramus	2.9	*2.0	2.5
32. Astaboras S.	3.2	3.1	3.1
33. Tithonius	2.6	2.2	2.4
34. Vexillum	3.5	2.9	3.2
35. Tartarus	—	2.7	2.7

* Poor.

Here we have widths ranging from eleven degrees to two. The widths given are those when the canal was at or sufficiently near its full strength, and are measured from the centres of the constituents. We notice two points: the agreement of the same canal with itself and its systematic disagreement with others. But what is especially to the point, if we compare the values found at successive oppositions, we find that for different canals the values agree in their difference. This shows that each of these values is, in most cases if not in all, a norm for that particular canal; a value distinctive of it and to which it either absolutely or relatively conforms. In other words, the width of the gemination is a personal peculiarity of the particular canal, as much an idiosyncrasy of it as its position on the planet.

Two general classes may be distinguished; those up to about five degrees in width apart and those above this figure. Whether such very widely separated lines as go to make up the second class, such as the Nilokeras I and II, constitutes a double is a debatable point. Schiaparelli thought they did, and so classed them. To me it did not at first occur so to consider them, and in some instances, such as the Helicon I and II, later observations seem to justify the omission. With the Nilokeras I and II the outcome seems the other way. The reasons for distrust of a physical rela-

tion between the constituents is not so much the distance separating them, nor any lack of parallelism, as the self-sufficient manner in which they show alone. Even this, however, tends to be recognized in the narrower pairs as they come to be better seen. It may be that width alone is wholly competent to selective showing. For the farther apart two lines are on the planet, the more opportunity is afforded the air waves to disclose the one without the other, a relative revelation which is constantly happening to detail in different parts of the disk. As long as any doubt exists of a physical community of interest, it seems best to distinguish such possibly merely parallel canals by suffixed numerals.

Of this class of doubles is the Nilokeras I and II. So wide is it that Mr. Lampland succeeded in photographing it as such, the two constituents showing well separated, and if it prove a true double it will be the first Martian double to leave its impress on a sensitive plate. Although separated by four hundred miles of territory, the two lines are parallel so far as observation can detect, which, of course, is not so very easy with the lines so far apart. In the country between one crosswise canal certainly lies, the Phryxus, and much shading thus far unaccounted for. Recent discoveries, however, point to the cause of such shading as lines imperfectly seen. For in some cases the lines

have actually disclosed themselves, and warrant us in believing that it is only imperfect seeing that keeps the others hid. Of the pair the Nilokeras I is itself double, curiously reproducing what sometimes is seen in the case of double stars, one of whose components turns out to be itself a binary. The second line of the Nilokeras I lies close to its primary on the north, and was on the only occasion of its detection the merest of gossamers, while the Nilokeras I itself stood out strong and dark. Thus do these Martian details increase and multiply in intricacy the better the seeing brings them out.

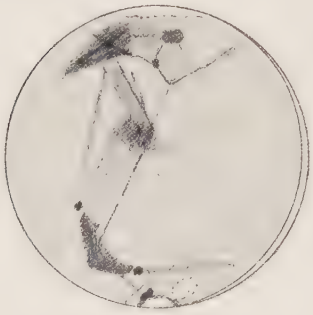
In the case of the other doubles, the doubles proper so to speak, there is every indication of a physical bond between the pair. What that bond may be is another matter and seems to be of different divulging, according to the particular instance. At one end of the subject, both as the widest of these doubles and one of the most important, stands the Ganges. The components of the canal are 5°.1 apart. This great width, joined to the fact of scant extension, gives the canal a stocky aspect, its breadth being but one sixth of its length. Its width draws attention to it while the phenomena it exhibits intrigue curiosity.

As early as the first opposition of my observations in 1894, the canal, as it underwent the process of doubling, showed phases of peculiarity. It was first caught by me as a double over toward the terminator,

or fading edge of the disk; then as it was brought nearer the centre by the gaining upon the longitudes, showed as a broad swath of shading of a width apparently equal to any it later exhibited. In this appearance it continued for some months, and then in October began to show a clarification toward the centre. Once started, the lightening of its midway advanced till at last, on November 13, it stood out an unmistakable double, the two lines standing where the edges of the swath had previously been. Had the observations here been all that one could wish, the method of gemination would have been certain and of great interest. Unfortunately, the observations left much to be desired, and those repeated in 1896–1897 and 1901 were of like doubtfulness. A period of swarthy confusion preceded the plainly dual state, but whether the double simply clarified or widened as well it was not possible to assure one's self. That the canal exhibited plainly the effects of seasonal development was as unmistakable as the steps themselves were open to ambiguity. In 1903 the canal was at its minimum and hardly to be made out. It seemed then to show an actual change in width coincident with alteration of visibility. But this, too, could not be predicated with certainty. It was also surmisable that the westernmost line was the one from which the development proceeded.

In 1905 much more was made out about it, training

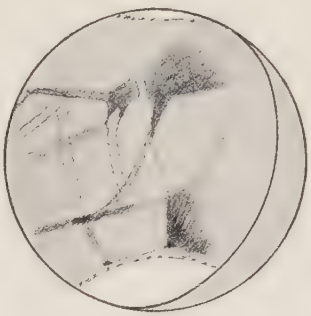
in the subject and increased proximity of the planet contributing to the result. It now became clear to me that the canal did develop from the western side; for the western edge made a dark line of definite boundary from which shading proceeded to the eastern side, where it faded almost imperceptibly off with no defined line to mark its limit. That this shading gradually darkened was evident, but that when it could be seen at all it extended to the extreme limit of the eventual double, restricted the character if not the fact of an actual widening. At this opposition, too, the canal passed through its period of minimum visibility and was then seen, whenever it could be caught, as a confused swath of full width. In the case of this canal, then, a widening in the sense of a bodily separation of two lines seems inadmissible. On the other hand, the gradual darkening of the swath, and especially the advance of the darkening from the western side, points to an interesting process there taking place.



Peculiar development of the Ganges.

At the opposite end of the series stands the Djihoun. As the Ganges is the widest of the instantly impressive doubles, so the Djihoun is the narrowest the eye has so

far been able to make out. Only two fifths of the width of the Ganges pair, this slender double is very nearly at the limit of resolvability. So well proportioned are its lines to the space between them, however, that in ease of recognition it surpasses many wider pairs. In form, too, it is distinctive, turning by a graceful curve the trend of the Margaritifer Sinus into the Lucus Ismenius. With its fundamental branch — the northern of the two — it joins what is evidently the main line of the Protonilus — also the northern one — to the Margaritifer Sinus's tip.



Djihoun, the narrowest double.

It differs from the Ganges in some other important particulars besides width. In its case no band of shading distinguishes it at any time. It has always been two lines whenever it has been seen other than as a single penciling; the only confusion about it being evidently our own atmosphere's affair. These two lines, furthermore, have showed, within the errors of observation, always the same distance apart. So that not only no change of intercommunication between the lines but no change in their places apparently occurs.

Between these extremes in width, two hundred miles

more or less for the Ganges and seventy-five miles for the Djihoun, the distance parting the pairs of most of the double canals lies. From 3° to 3°.2 on the planet may be taken as that of the average; the degrees denoting latitudinal ones on the surface of Mars, the length of which is equal to thirty-seven of our English statute miles.

Most of the canals conform apparently to the type of the Djihoun rather than to that of the Ganges. Careful consideration of them fails to find any increase or decrease of distance, between the pairs of the same canal at different times, which cannot be referred to errors inevitable to observation of such minute detail. In short, the double is made by the addition of a second line in a particular position and not by a growth out to it of a line coincident to begin with with the first.

I have said that the average width between the two lines of the doubles was about 3°. It must not be supposed that this average width denotes anything more than an average; or, in other words, that it denotes anything in the nature of a norm. The remark is important in view of a suggestion which I have heard made that we have here a system based on fundamental Martian units, in which, or in multiples of which, the dimensions of the canals are implicitly expressed. Such, however, does not seem to be the case. In some instances, indeed, we have certain evidence to the con-

trary and that the width of the double is conditioned solely by antecedent place. The Phison and Euphrates offer a case in point. These two important arteries in duplicate leave, as we saw, from two carets in the Mare Icarium, the Portus Sigaei, held in common tenancy by both. Each pair then proceeds down the disk inclined at its own particular angle to the meridian in order to reach by a great circle course a certain spot; the Pseboas Lucus in one case, the Luci Ismenii in the other. As one of these angles is thirty-five degrees while the other is only three, they must, from the circumstances of their setting out, have not only different widths, but widths determinately different in advance, since each is, roughly speaking, foreshortened by the degree of divergence from the meridian. The one, therefore, must be about four degrees to the other's something less than three and a half. This is what they actually are as determined by measurement from observation. That the calculated value agrees with that found from observation helps certify to a community of starting-points, but it completely does away with comprehensive design in the question of their widths. For if the one were so settled, the other could not be.

Indeed, the next example seems to deny it to both. This example occurs, too, not far away from the scene of the first, in the twin bays of the Sabaeus Sinus, from which depart, *mutatis mutandis*, the

double Hiddekel and the two Gihon. These twin gulfs bear so little imprint of being other than natural formations, that they have been universally and very likely quite rightly taken for such ever since Dawes discovered them in 1859, long before things like canals were dreamed of. It is strange that when the Hiddekel and the Gihon were found by me to be double in 1897, with a branch of both leading from each bay, the connection between the sceptically scouted doubles and the thoroughly believed-in bays should have been apparent. For to link a ghost to materiality, if it does not discredit the materiality, serves to substantialize the ghost. Furthermore, it shows that in this case neither the one double nor the other can have had its width engineered on any preconceived scale, unless the twin bays be themselves so accounted for. So that it seems useless to seek for cryptic standards in the canals or to think to find them a measure of value from the fact of their being a medium of exchange.

The Sabaeus Sinus, embouchure for the double Hiddekel and Gihon.

A third instance of the same thing in the case of the Ganges and the Jamuna was proved at the last opposition after having long been suspected without my

being able to make sure of it. These instances, taken in connection with the wide range of values in the widths presented by different canals, serve to show that the distance between the twin lines is an individual characteristic of the particular canal, and further to point to its cause, in some cases certainly and possibly in all, as topographical. The duplicate line makes a convenience of a neighbor, and suits its distance from its fellow to friendly feasibility. To cut a 'canal' to conform to the country seems logical if not obligatory, and quite in keeping with the nomenclature of the subject; but here the starting-point appears to be the only thing considered — the canal once safely launched being left to shift, or rather not shift, for itself.

IV

Topography thus introduced to our notice for its effect on the breadth of the doubles proves upon inspection to be of extended application to the whole subject. Examined for position these canals turn out to have something to say for themselves bearing on the question of their origin and office.

With regard to position, probably the first query to suggest itself to an investigator to ask is of the direction in which they run. Is there a preponderance manifest in them for one direction over another? Do they show an inclination to the vertical, to the horizontal,

or to some tilt between? To answer this we may box the compass, and taking the four cardinal points with the twelve next most important points between for sectional division segregate the doubles according to their individual trend. As we have no means of determining in which sense any direction is to be taken, — if indeed it is not to be taken alternately in each, — we get eight compartments into one or the other of which all the doubles must fall. This they do in the following manner: —

S. & N., Laestrygon, †Fretum Anian, Aethiops, Amenthes, Titan, †Dis, †Is	7
S. S. E. & N. N. W., †Gihon, Ganges, ‡Tithonius, Euphrates, Adamas	5
S. E. & N. W., †Eunostos, Triton, Tartarus, Naarmalcha	4
E. S. E. & W. N. W., †Astaboras, Typhon, †Pierius	3
E. & W., †Nar, †Protonilus, *Propontis, ‡Nectar, †Cocytus, †Chaos,	6
E. N. E. & W. S. W. †Deuteronilus, †Callirrhoe, †Cerberus N., Cerberus S., †Sitacus, †Erebus	6
N. E. & S. W., †Djihoun, *Nilokeras I & II, †Avernus, †Nepenthes, Gigas, †Alander, Polyphemus, †Gelbes, †Marsias, †Pyramus, †Nilokeras I, Asopus	12
N. N. E. & S. S. W., Jamuna, Phison, †Hyblaeus, Cyclops, Lethes, †Thoth, †Vexillum, †Hiddekel	8
	51

No conclusively marked preponderance for one direction over another manifests itself by this partitionment. Nevertheless, a certain trend to the east of

*Wide canals. †Northern hemisphere exclusively.
‡Southern hemisphere exclusively.

north, as against the west of north, is discernible. More than twice as many doubles run northeast and southwest or within forty-five degrees of this as do similarly northwest and southeast, there being twelve of the latter and twenty-six of the former. That this seems to mean something the nearly equal pairing of quadrantal points goes to show. Thus: —

N. & S. and E. & W. inclined canals number . .	7 +	6 =	13
N. N. E. & S. S. W. and E. S. E. & W. N. W. inclined canals number	8 +	3 =	11
N. E. & S. W. and S. E. & N. W. inclined canals number	12 +	4 =	16
E. N. E. & W. S. W. and N. N. W. & S. S. E. inclined canals number	6 +	5 =	11
	33	18	51

a fairly equable division in direction. A trend to the westward would be given a particle descending from the north to the equator by the planet's rotation, thus turning it southwesterly; and one to the west to a particle travelling equatorwards from the south, turning it northwesterly. As the doubles lie in the northern hemisphere, either in whole or part, to the extent of 93 %, this might account for the preponderating tilt to the east of north and west of south exhibited by them. It would correspond with the lines of flow.

To see whether this be so we will take only those double canals that lie exclusively in the northern and southern hemispheres respectively, and note those in

the former that trend to the west of south as against those that run to the east of it, and *vice versa* in the southern. In the northern the proportion of the westerly to the easterly ones is 17 to 4; in the southern, 1 to 0 the other way.

Of those whose course is common to both hemispheres we find for the ratio of the southwesterly to the southeasterly 8 to 7. But the proportion of the course of these canals in the two hemispheres is on the side of this same ratio.

From their direction we now pass to consideration of their distribution in longitude. It appears that some meridians are more favored than others. The hemisphere which has the Syrtis Major for centre is more prolific in them than its antipodes. From longitude 80° to 200° there are ten doubles, from 200° to 320° twenty-four, and from 320° to 80° seventeen; or, roughly, in the proportion of 2, 5, and 3. That this distribution means anything by itself is doubtful; it is much more likely to be a general topographical consequence of their distribution in another direction, which proves to be highly significant and which we shall now expose — that of latitude.

If we separate the surface into zones, each ten degrees wide, and count the doubles found traversing in whole or part the several zones, we find the following arrangement: —

Double Canals of Mars arranged according to Latitude		At Opposition of 1903 Alone	At All Oppositions so far observed at Flagstaff
Between 30° S. and 20° S.	Tithonius, Nectar, Laestrygon . . .	2	3
Between 20° S. and 10° S.	Jamuna, Ganges, Gigas, Laestrygon, Cyclops, Titan, Tartarus, Polyphemus, Tithonius .	7	9
Between 10° S. and 0°	Jamuna, Ganges, Gigas, Laestrygon, Cyclops, Cerberus S, Aethiops, Lethes, Amenthes, Triton, Phison, Euphrates, Titan, Tartarus, Adamas, Typhon, Vexillum, Asopus, Naarmalcha, Polyphemus .	15	20
Between 0° and 10° N.	Gihon, Djihoun, Jamuna, Ganges, Gigas, Laestrygon, Cerberus N, Cyclops, Cerberus S, Eunostos, Aethiops, Lethes, Amenthes, Triton, Nepenthes, Phison, Euphrates, Sitacus, Hiddekel, Tartarus, Adamas, Asopus, Typhon, Vexillum, Cocytus, Is, Avernus N, Naarmalcha, Polyphemus	21	29

Double Canals of Mars arranged according to Latitude		At Opposition of 1903 Alone	At All Oppositions so far observed at Flagstaff
Between 10° N. and 20° N.	Gihon, Djihoun, Jamuna, Nilokeras I and II,[1] Nilokeras I, Ganges, Gigas, Eunostos, Aethiops, Lethes, Amenthes, Thoth, Astaboras, Phison, Sitacus, Euphrates, Hiddekel, Adamas, Asopus, Gelbes, Avernus N, Erebus, Naarmalcha, Vexillum, Is, Dis .	18	26
Between 20° N. and 30° N.	Gihon, Djihoun, Jamuna, Nilokeras I & II,[1] Nilokeras I, Alander, Hyblaeus, Lethes, Amenthes, Thoth, Sitacus, Astaboras, Vexillum, Phison, Euphrates, Hiddekel, Adamas, Eunostos, Aethiops, Gelbes, Avernus N, Naarmalcha, Is . .	17	23
Between 30° N. and 40° N.	Deuteronilus, Alander, Nar, Marsias, Fretum Anian, Amenthes, Thoth, Vexillum, Phison, Euphrates, Hiddekel, Adamas, Eunostos, Djihoun, Gihon, Nilokeras I, Chaos, Gelbes, Aethiops, Naarmalcha,	12	20

[1] Very wide and possibly not of the same class.

Double Canals of Mars arranged according to Latitude		At Opposition of 1903 Alone	At All Oppositions so far observed at Flagstaff
Between 40° N. and 50° N.	Fretum Anian, Pyramus, Protonilus, Propontis[1]	3	4
Between 50° N. and 60° N.	Callirrhoe, Fretum Anian, Pierius . . .	3	3
Between 60° N. and 63° N.	Pierius, Callirrhoe . .	2	2

From this tabulating of them it is apparent that the doubles are practically confined to the zones within forty degrees of the equator. Only 7 % of them straggle farther north than this, while above 63° north latitude and 35° south latitude there are none. Such a distribution is not in proportion to the areas of the zones, which though diminishing toward the poles do so at no such rate. The surface included between the equator and 40° of latitude is 65 % of the hemisphere, whereas the fraction of the number of doubles found there is 93 %. The doubles are, then, an equatorial feature of the planet, confined to the tropic and temperate belts.

To perceive the tropical character of the doubles in another way we have but to consider the zonal distribution of the single canals. Unlike the former the

[1] Very wide and possibly not of the same class.

latter do not thin out as one advances toward the poles; since in the arctic regions single canals bemesh the surface as meticulously as elsewhere. It is only that they there replace the doubles; or, not to put the cart before the horse, it is the doubles that in part replace the singles in the tropics. And that this arrangement has something physical behind it by way of cause is curiously shown by two canals, the Arnon and the Kison, which are neither of the one kind nor yet the other, but a cross between the two. For the Arnon and the Kison are convergent doubles; the two lines of the Kison leaving a common point at the edge of the polar cap and separating as they travel south, while the two Arnon take up and continue the divergence, connecting at last with the parallel pair of the Euphrates. These canals thus make transition between the true doubles and the true singles, and may be looked upon as endowed with the potentialities of both. From their association with the double Euphrates, it is clear that the transition between the two forms is not only formal but physical, and that the stopping of the dual condition at the fortieth parallel is not the outcome of chance.

It may occur to the thoughtful that the doubles appear confined to the more tropical portions of the planet because of a better presentation of those zones, the reader supposing the planet to be seen axised perpen-

dicularly to the plane of sight, as geographies represent the earth's globe. The supposition, however, is erroneous. We sometimes see the planet so, but more often not. Such is the tilt of the Martian axis to the plane of the Martian ecliptic that the different zones are rarely seen on an even keel, so to speak, their aspects shifting totally from one opposition to another. What shows in mid-disk on one occasion may be forty-eight degrees removed from it at another, a distance amounting to three-quarters of the way from apparent equator to apparent pole.

Thus the double canals are for some intrinsic reason equatorial features of the planet as opposed to polar ones. And this not simply because of greater space there. Duality is a result of conditions intrinsic to the several localities. What the cause may be is related to the character of the things themselves, which we shall later consider. For the moment we may note that the fact disposes quietly of the diplopic theory of their manufacture. For, for diplopic doubles to show such respect for the equator would betoken a courtesy in them to be commended of Sydney Smith.

But this is not their only geographic bias. In addition to not being partial to the poles, the double canals show a certain exclusiveness toward the dark areas generally. Not only do they avoid the arctic and antarctic zones entirely, but they largely shun the blue-

green regions. In these but two suspicions of doubles occur, in the Aonium Sinus, although single canals there are as numerous as anywhere else on the planet.

Nevertheless, although they avoid running through them, they run from them in a manner that is marked. Proceeding from the great diaphragm are no less than 28 out of the 53 doubles. Connecting directly with these are 17 more; while the remaining 8 are also associated through the intermediarism of dark areas, the Solis Lacus and the Trivium.

In like relation to dark regions, they are limited on the north by the Mare Acidalium, the Propontis, the Wedge of Casius and their interconnecting bands, the Pierius, Callirrhoe, Helicon. In this manner do they form a broad girdle round the planet's waist, leaving the polar extremities bare.

CHAPTER XIX

CANALS IN THE DARK REGIONS

SEVENTEEN years after the recognition of the canals in the light regions occurred another important event, the discovery of a similar set in the dark ones. The detection of these markings in the dark areas was a more difficult feat than the perceiving of those in the light, and in consequence was later accomplished. Also was it one where recognition came by degrees.

I have previously pointed out what this discovery did for the seas — nothing less than the taking away of their character in a generally convincing manner. To one who had carefully considered the matter, the seas had indeed already lost it, as was shown in Chapter X, but to those who had not these canals presented a very instant proof of the fact.

From such not wholly supererogatory service they went on to furnish unlooked-for help in other directions. Their discovery showed in the first place that no part of the planet's surface was free from canal triangulation.

But it did more than this. For these canals in the dark regions left the edge of the 'continents' at the

very points where the canals of the light regions entered them, which fact proved for them a community of interest with the latter. Such continuation was highly significant, since it linked the two together into a single system, compassing the whole surface of the planet. Starting from the places where the light-region canals come out upon the great girdle of seas that stretches all round the planet, most of the new canals headed toward the passes between the islands south, as nearly polewards as circumstances of local topography would permit. In the broader expanses of the Syrtis Major and the Mare Erythraeum, besides main arteries others went to spots in their midst after the same fashion as those of the light regions. These spots differed in no way apparently from their fellow oases elsewhere. From a spot in the centre of the Syrtis three great lines thus traveled south: the Dosaron, heading straight up the Syrtis on the meridian till it struck the northernmost point of Hellas; the Orosines, inclined more to the right, passing through the dark channel to the west of that land and so proceeding south; and lastly the Erymanthus turning eastward till it brought up finally at the Hesperidum Lucus. Where, on the other hand, the long chain of lighter land, called by Schiaparelli islands, and stretching from the Solis Lacus region westward to Hellas, offered only here and there an exit, the canals made for these exits. The canals in the Mare

Sirenum, the Mare Cimmerium, and the Mare Tyrrhenum struck more or less diagonally across those seas from their northern termini to the entrances of the straits between the islands, thus lacing the seas in the way a sail is rolled to its spar. From the exact manner in which they connected with the light-region canals they proved the two to be part and parcel of one system, which in its extension was planet-wide and therefore proportionately important. Whatever of strange interest the curious characteristics of the canals themselves suggested was now greatly increased by this addition; for the solidarity of the phenomenon affected the cogency of any argument derived from it.

In 1894 only the dark areas of the southern hemisphere were found to be thus laced with lines. For then so great was the tilt of the planet's south pole toward the earth, that while those zones were well displayed the dark patches of the northern hemisphere were more or less hull-down over the disk's northern horizon.

Contrast was the open sesame to their detection. When the *maria* show dark, the lines are lost in the sombreness of the background. As the *maria* lighten the lines come out. Such was amply witnessed by the effect in 1894 and 1896. In 1894 I found it impossible to perceive them, except where the Padargus crossed Atlantis, for the hue of the *maria* themselves was then very dark. In 1896, on the other hand, I saw

them without difficulty. What is also of interest: so soon as seen they appeared small, without haziness or distention.

As the oppositions succeeded one another the northern regions rose into view, and with their appearance came the detection in them of the same phenomena. No large dark areas like the diaphragm exist there, but the smaller patches of blue-green which bestrew them proved to be similarly meshed. At first canals were evident upon their peripheries, contouring them about; then the bodies themselves of the patches showed grid-ironed by lines.

The Mare Acidalium with its adjuncts, the Lucus Niliacus on the south and the Lacus Hyperboreus on the north, thus stood out in 1901. On a particularly good evening of definition at the end of May, the Mare suddenly made background for a sunburst of dark rays, six of them in all radiating from a point between it and the Lacus Hyperboreus. Considering how sombre the Mare was at the time, this was as remarkable a vision as it was striking to see. Although at the moment the sight was of the nature of a revelation, these lines have been amply verified since, as the Martian season has proved more propitious.

Similar decipherment has befallen all the other patches of blue-green in the northern hemisphere; these having shown themselves first circumscribed and

then traversed by canals. Interesting instances were the Wedge of Casius and the Propontis. These markings, first perceived years ago as mere patches of shading, then partially resolved by Schiaparelli, now stood revealed as a perfect network of lines and spots. So many of both kinds of their detail occupied the ground that to identify them all was matter of exceeding difficulty. The outcome is shown in the diagrammatic representations opposite and on page 256.

The Propontis, 1905.

These drawings disclose better than any description the mass of detail of which the patches are in reality composed, and serve to convey an idea of the complexity involved. If the general canal system seem intricate, here is something which exceeds that as much again.

The extension in this manner of the curious triangulation of the light areas into and through all the dark areas as well, by thus spreading the field of its operations over both terranes complexioned so unlike, greatly increases the cogency of the deduction that this detail is of later origin than the background upon which it rests. That the mesh of lines covers not only the ochre stretches of the disk, but the blue-green parts as well, makes it still more certain that it is not a sim-

ple physical outcome of the fundamental forces that featured the planet's face. For in that case it could not with such absolute impartiality involve both alike. Thus here, again, we find corroboration by later observations of what earlier ones established.

A last link in the chain of canal sequences remains to be recorded. Just as the lines in the dark regions continued those in the light, so they themselves turned out to be similarly prolonged and in no less suggestive a manner. For when the north polar zone came to be displayed, canals were evident there, continuing those in the other zones and running at their northern ends into dark spots at the edge of the polar cap. Here, then, we have the end of the whole system, or more properly its origin, in the polar snows. The significance of this will be seen from other phenomena, to a consideration of which we now proceed.

CHAPTER XX

OASES

NEXT to be caught of the details of this most curious network that meshes the surface of Mars was a set of phenomena stranger even than the lines; to wit, dark round dots standing at their intersections. More difficult to make out than the lines, they were in consequence detected thus later by fifteen years. Once discovered, however, it became possible to trace their unconscious recognition back in time. Thus Schiaparelli told the writer in 1895, apropos of those found at Flagstaff, that he had himself suspected them but could not make sure. Some of them stand figured in his *Memoria Sesta* dealing with the opposition of 1888, but not published till 1899. In such posthumous recognition, as one may call it, the spots repeated the history of the canals. For Schiaparelli had himself pointed out a similar preconscious visioning of the canals in the delicate pencilings of Dawes and the streaks of Lockyer, Kaiser, and Secchi, now translatable as representing the Phison, the Euphrates, and half a dozen other canals imperfectly seen. That both the canals and the oases were thus sketched before they were seen

well enough to be definitely discovered is to an unprejudiced mind among their strongest credentials to credit.

Nor was Schiaparelli the sole person thus to get proof before letter. One of their very earliest portrayals appears in a drawing by Otto Boeddicker, made on December 26, 1881, where the Pseboas Lucus is clearly represented. In a still more imperfect manner some of the spots had been adumbrated and their shadows drawn long before that. Thus they may be deciphered as the cause of patches drawn by Dawes in 1864, though none of them were in any definite sense detected till 1879, and only then so ill defined that their true character was not apparent. As patches they are still commonly seen at observatories where the observational conditions are not of the best and the study of the planet not systematically enough pursued to have them disclose their true shape and size.

The history of their detection is resumed in the experience of the individual observer. During the course of my own observations I have had occasion to notice the several stages in recognition of the spots which have marked their chronologic career. As with the lines, three stages in the appearance of the spots may be remarked: first, where the scattering of the rays is so wide that dilution prevents anything from being seen; second, where the commotion being less

the object appears as a gray patch; and third, where in comparative quiet it condenses into a black dot. For the two former our own air waves are to blame. In coursing waves of condensation and rarefaction they spread the image of the spot as they do that of the canal. Then as the currents calm the spot shrinks to its normal proportions, and in so doing darkens in consequence of being less widely diffused. Thus the evolution in perception which may take place in the course of an hour for a particular observer represents exactly what has occurred in the person of the race by the improvement in observational methods and sites.

That the spots, although wider than the canals, remained longer hidden from human sight, is due to the optico-physic fact that a tenuous line may be perceived *owing to its length* when a dot of the same diameter would be invisible. Summation of impressions is undoubtedly the cause of this. The mere fact that a row of retinal cones is struck, although each be but feebly affected, is sufficient to raise the sum total into the sphere of consciousness.

In the second stage of their visibility, the spots are in danger of mistake with the smaller true patches of sombre hue which fleck the northern hemisphere of the planet and from which they differ totally in kind, totally so far as our present perception goes. Such true patches consist of a groundwork of shading, upon which,

indeed, are superposed the usual network of lines and spots. Prominent as instances of them are the Trivium Charontis, the Wedge of Casius, and the Mare Acidalium. With patches of the sort the spots proper must not be confounded.

Close treading on the heels of the detection of lines athwart the seas came the recognition of spots there likewise. At the opposition of 1896–1897 the number was added to; and so the tale has been steadily increased. Their number as found at Flagstaff up to the present time, that is, to the close of the opposition of 1905, is 186; of which 121 lie in the light regions, 42 in the dark areas of the southern hemisphere, and 23 in the smaller sombre patches of the northern zones.

From their relationships and behavior it became apparent that the spots were not lakes but something which answered much more nearly to oases.

Of the spots three kinds may be distinguished: the large, the little, and the less, if by the latter term it may be permitted to denote what has but collateral claim to be included and yet demands a certain recognition. For though not spots like the others, the members of the third class have certain traits in common with them while differing radically in others.

To the kind called large belong the greater number of spots so far found upon the disk. They are large only by comparison with the little. For they measure

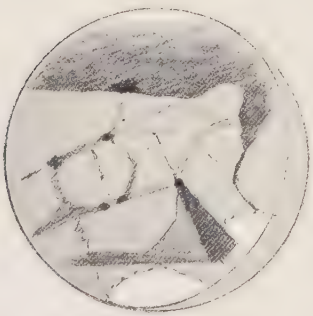
according to my latest determinations but seventy-five or one hundred miles in diameter; on the planet some two degrees across. Sizable black pin-heads, it is their tone that chiefly catches the eye, for they are commonly the darkest markings on the disk. Against the ochre stretches they appear black, and even in the midst of the dark areas they stand out almost as much contrasted with their surroundings as these do with the light regions themselves. About a hundred and forty are now known. Those in the light areas were discovered first; those in the dark regions being harder to see.

Of this first kind are such spots as the Pseboas Lucus, the Aquae Calidae,the Lacus Phoenicis, and the Novem Viae; or, in English, the Grove of Pseboas, the Hot Springs, the Phœnix Lake, and the Nine Ways, to mention no more. That they bear dissimilar names implies no dissimilarity in structure. The phenomena are all remarkably alike, and clearly betoken one and the same class of objects; differing between themselves at most in size and importance.

In form they all seem to be round. They certainly appear so, and were it not that retinal images of small areas tend to assume this shape might implicitly be credited with being what they seem. The reason for optical circularity probably resides in the shape of the retinal cones and in their patterning into a mosaic

floor. So that unless a sufficient number of cones be struck the image takes on to consciousness a roughly circular figure — whether it be so in fact or not. In the present case, however, they seem to be too well seen for self-deception of the sort.

The little are distinguished from the large by being pin-points instead of pin-heads. They are most minute; from fifteen to twenty-five miles in diameter only. That anything except size distinguishes the two apart is from their look improbable. In color or rather tone, — for distinctive color is of such minute objects unpredicable, — they would seem to be alike. Such is also the case with their distribution and detail association.



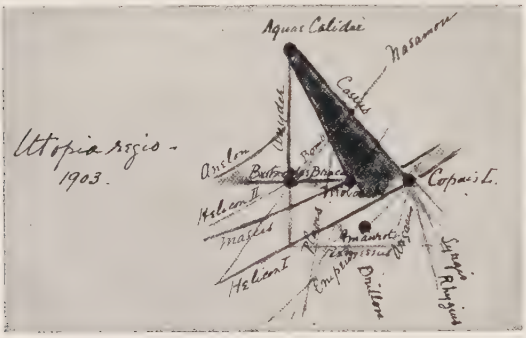
Fons Immortalis, June 19.

To the second class belong the Fons Juventae, — Schiaparelli's Fountain of Youth, — the Fons Immortalis in Elysium in 1905, and the Gygaea Palus, besides many more. These are all pin-points, just upon the limit of vision, and noteworthy chiefly for being visible at all. All those detected so far lie not very distant from the equator, which may or may not be a matter of accident. It is not one of perception, since this part of the planet was not the best place for observation at

the time they were discovered. To make out one of these little dots is a peculiarly pleasing bit of observation, as it requires particularly good definition. One might almost take them for fly-specks upon the image did they not move with the disk. They have no perceptible size and yet are clearly larger in diameter than the canals which run into them; which proves how very slender the latter must be.

Very early in the detection of the spots it became evident that they were not scattered haphazard over the surface, but that on the contrary they were never found except at the meeting-points of the lines. From this it must not be supposed, as has been done, that the spots are merely optical reinforcements of the lines at their crossings due to the more crowded character there of the lines themselves. That they are not such is demonstrated by the existence of crossings where, either temporarily or permanently, none appear; which shows that they are far too well seen for any such illusion about them to be possible. At these crossings the lines traverse one another without thickening, whether they be single or double lines. The spots, on the other hand, are much wider than the lines, giving a beaded look to the threads. In short, they are the knots to the canal network. All the more important junctions are characterized by their presence. Such starred junctions are not confined to the ochre

regions; they dot the light and the dark areas with equal impartiality, thus showing themselves to be independent of the nature of the ground where large stretches of country are concerned. On the other hand, they appear to be unusually numerous in the smaller, isolated, dark areas of the northern hemisphere, such



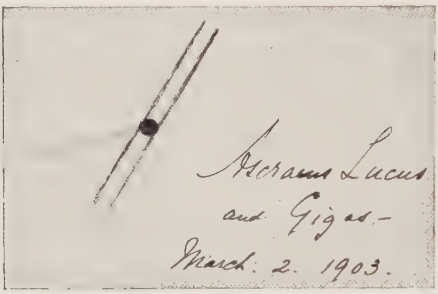
as the Trivium, the Mare Acidalium, the Propontis, and the Wedge of Casius. Here they crowd; and one cannot avoid the inference that their plentifulness in these regions is not due to chance.

To the large spots, those of the first class, fall the places of intersection of the largest and most numerous canals, while the little spots make termini to fainter lines, ones that bear to them a like ratio of unimportance. Spots and lines are thus connected not simply in position but in size. The one is clearly dependent on the other, the importance of the centre being gauged by the magnitude of its communications.

From the fact of association we now pass to the manner of it, which is quite as remarkable. The position of the spot relative to its tributary canals depends upon the character of the connecting lines. If the canal be single it runs, so far as may be judged, straight into the middle of the oasis, or, in other words, the oasis is symmetrically disposed about its end. This is true of the greater number of the large spots and of all the little ones, since the latter have as connections only single canals.

In the case of a double canal arriving at a spot, a different and most curious dependence is observable. This fact I first noticed in a general way at the opposition of 1896–1897, the initial appearance of it being presented on September 30, 1896, by the Coloe Palus and the Phison. It was again visible in the case of the spots in the Trivium at the time the canals leading to that place doubled in March, 1897. But the exact nature of the phenomenon was not fully appreciated till 1903, when the thing was seen so well as to appear cut on copper plate. It was this: the spot is exactly embraced between the two arms of the double canal. It is, moreover, seemingly perfectly round and just fits in between the parallel lines. The Ascraeus Lucus was the first spot that showed thus in association with the double Gigas. Others followed suit in so showing, several specimens presenting themselves so well as to

leave no doubt of the precise connection. The sight presented by such a spot and its incasing double is a beautiful bit of detail, perhaps the most beautiful so far to be seen upon the Martian disk. The distinctness with which it stands out on occasion suggests a steel engraving, and shows how clear-cut the Martian features really are when our own air ceases from troubling and allows them to be at rest. Incidentally, we may note that this phenomenon alone serves to disprove the diplopic theory of the production of the double canals. For if a double were a single line seen out of focus, any spot upon it should be doubled too.



It may seem to the reader as if what was seen in 1903 was but an unimportant advance over the observed phenomena of 1896–1897. Not so, however. For with the earlier instances it was not possible to be sure of the precise limits of the spot with regard to the double. The Coloe Palus, on the one hand, did not fill all the space apparently between the double Phison; while the Lucus Ismenius more than did so with the double Euphrates. To have set down the

different appearances to insufficient definition would have been a great mistake, as subsequent observation has served to show. The Lucus Ismenius instances this. In 1896–1897 it was seen terminating the Euphrates, blocking all the space between the two lines and extending a little upon either side of them. Now, from its appearance in 1901 it was evident that the effect had been produced by twin spots lying along the Deuteronilus, the axis joining them being perpendicular to the Euphrates. In 1903 the relation was still better explained by what appeared then, when not only did the two spots stand out, but the Euphrates showed with a line running centrally into each.

Although originally seen by Schiaparelli as a single spot and so at first seen by me, better acquaintance with the disk disclosed to both observers its really dual character. As this pair has persisted through all three of the most recent oppositions, it seems fairly certain that it is always of this character, and more fitting, therefore, to give it the plural appellative. This is the single instance of a double oasis. There are many that lie close together and might be taken as such; but this is the only one where the connection is intrinsic. According to measures of the drawings of 1905 extending through six presentations, the distance between the twin oases is 4°.2.

Their relation to the canals which run into them is of

the most complicated description and of the most suggestive character. For to the twin spots converge no less than seven double canals, one wedge-shaped pair and three single canals, a most goodly number of communication lines. Four of the double canals run into the oases with one line to each; these canals are the Astaboras, the Naarmalcha, the Euphrates, and the Hiddekel. Three doubles, the Protonilus, the Djihoun, and the Deuteronilus, embrace the oases between their two lines, while, in the singles, the canal connects with one or other of the twins, as the case may be.

Now, there is method as to which of the doubles shall straddle, which embrace, the two Ismenii. Those which leave the place parallel or nearly so to the direction joining the Luci, inclose them both; those of which the setting forth is at an angle to this direction depart, each line of the pair, from the eastern and the western spot respectively.

Peculiar association of the Luci Ismenii with double canals.

Consider, now, the disposition of these seven pairs of lines. All of them lie in one semicircle about the Luci, beginning with the Protonilus on the east and ending with the Deuteronilus on the west. Furthermore, all follow approxi-

mately arcs of great circles, except the Djihoun, and all send one of their twin lines to one Lucus, one to the other. The data are enough to make this statement possible. Although the west line of the Naarmalcha has not been caught entering its oasis, the east one has been seen to enter the other, and the width of the double shows that the west one must enter the corresponding spot. In the case of the Astaboras the double has only been observed as far as the Vexillum, but the south line has continued on to the west Ismenius, and here again the width makes it certain that were the canal double throughout, the other line must enter the east Ismenius. From the base line of the Proto-Deuteronilus the inclinations of the seven pairs are as follows: —

Protonilus	0° Due East
Astaboras	40° North of East
Naarmalcha	70° North of East
Euphrates	80° North of West
Hiddekel	55° North of West
Djihoun	0° North of West
Deuteronilus	0° Due West

Now, the width between the two lines of the four canals to the east increases regularly from the Protonilus round; the Protonilus being the narrowest double, the Astaboras the next, the Naarmalcha the next, and the Euphrates the widest. And from the width between the twin oases, it would seem that they severally enter

the centres of them. What takes place in the case of the Hiddekel, which is wider than its tilt would imply,

and in the Djihoun, which is narrower, is not so clear. But that they enter the oases in some place is certain.

The spots make common termini for all the canals of a given neighborhood. In other words, canals converge to the places occupied by the spots and do not cross haphazard according to the laws of chance. Only one instance exists where a spot fails to gather to itself the whole sheaf of canals and even there it collects all but two. This anomaly is the Pseboas Lucus. The peculiarity of this oasis is that it lies not on, but just off, the Protonilus. That it does so is exceeding curious, considering that it is the sole example of such extra-canaline position. Strictly speaking, it is not the Protonilus but the point where the Protonilus turns into the Nilosyrtis to which it stands thus neighboringly aloof. And this may explain the anomaly. For the Nilosyrtis has not the full geometric regularity of the normal canal, and seems to have been a more or less fundamental feature of the region.

For the rest, the Lucus has the form and possesses the canal connections appropriate to its state. It is apparently round, and lies between the twin lines of the Phison and also between those of the Vexillum.

Not far from the Pseboas Lucus are to be found all the examples of the third class of spots; for so far they have not been observed outside of Aeria, a region peculiarly peopled by double canals. With double canals they are necessarily associated, inasmuch as they consist of shading in the form of a square or parallelogram, filling the deltas between two pairs that cross. Thus have shown the Coloe Palus at the crossing of the double Phison with the double Astaboras, and the Juturna Fons where the double Sitacus traverses the double Euphrates.

At these same places a fourth kind is sometimes noticeable: a four-square set of pin-points or a two-square set of the same at the corners of the line-made parallelogram. This kind may well be synchronous with the third, though it has only been noticed at consecutive presentations. The third, however, has no observed dependence upon the first or second classes. And this serves to make more probable the true objectivity of the circular and the square figures respectively shown by each.

The spots apparent in the dark regions do not appreciably differ in either size or shape from the bulk of

those visible in the light. Equally with them they seem to be round, small, and nearly black. They would seem, too, in the great diaphragm — or larger contiguous sombre region — to be equally plentifully distributed.

CHAPTER XXI

CARETS ON THE BORDERS OF THE GREAT DIAPHRAGM

FUNCTIONALLY related to the canal system, and yet in look and location contrasted with its other details, is a further set of markings, detected by me in 1894, and reseen at subsequent oppositions since, along the north border of the southern seas. They lie upon what used to be thought the continental coastline, the fringing edge of that almost continuous band of shading that belts the Martian globe throughout the southern subtropic zone and called by Schiaparelli the great diaphragm. The terrane lends itself to the appellative, forming, as it does, a dark dividing strip of country between the brilliant reddish-ochre hemisphere on the north and the half-toned islands to the south of it. By Schiaparelli it was thought to be one long Mediterranean, and though its marine character is now disproved, that it lies lower than the bright ochre regions is likely. To this difference of level is probably due the peculiar phenomenon which there manifested itself to careful scrutiny in 1894. For it was there only that it occurred.

The phenomenon in question consisted of nicks in

the coastline, of triangular shape and filled with shading. They occurred at intervals along it and were of the general form of carets, such marks as one makes in checking items down a list. Their position was always where a canal debouched from the diaphragm upon its career across the open continent. The canal itself was by no means necessarily visible. On the contrary, at first it was usually absent. Such was the case with those marking the departure-points of the Phison and Euphrates and of the Amenthes and Lethes, which appeared, without being well defined, from the moment the planet came to be scanned.

One by one these carets stood out to view, punctuating the points where canals later were to show or terminating those that already existed. Strung thus with them at intervals was the whole coastline of the diaphragm, beginning with the Mare Icarium and stretching round through the Mare Tyrrhenum, Mare Cimmerium, Mare Sirenum, and Mare Erythraeum to the Mare Icarium again. As the planet got nearer to the earth their peculiar shape began to define itself, and it was again in the case of those giving origin to the Phison and Euphrates that the recognition came first. What had appeared earlier simply as a spot now stood out as two triangular notches, indenting the coast and giving exit at their apices, the eastern one to the Phison, the western to the Euphrates. These were the things,

then, that had constituted the Portus Sigaeus of Schiaparelli.

Commonly the carets lie at the bottom of well-marked bays, as, for example, those terminating the Syrtis Minor and the Sinus Titanum. But frequently they are placed in the very midst of a long and otherwise unaccented coast, as is the case in mid-course of the Mare Cimmerium and the Mare Sirenum. Yet in no instance is the thing unassociated with a canal. In every case one or more canals leave the caret for their long traverse down the disk.

This is not their only canal connection. When the canals in the dark regions came to be discovered, each of them was found by me, as nearly as difficult observations would permit, to be associated with the caret upon its other side. Thus the lacing of the Mare Cimmerium and Sirenum used them as its reeving-points. Similarly those at the mouths of the Phison and Euphrates did duty likewise to the Maesolus and the Ion. In such manner the carets stood in dual relation to canals; subserving a purpose to the light-region canals on the one hand and to the dark-region ones on the other. In a way the caret, then, holds the same position toward the canals that do the spots in the light or dark regions. Like them it is a canal-distribution point. Unlike them, however, in shape it is triangular instead of round, and we are piqued to inquire to what cause

it can owe its different contour. The answer seems to lie in the character of the locality, not simply in its complexion. For the spots in both the northern and the southern dark patches are as circular as those standing in the light, whether they lie in the centre or upon the edges of them. The edges of the northern patches, however, and the other sides of the southern ones do not present the clear-cut character of the northern coast of the diaphragm. Where they seem to be definitely bounded they are so by darker canals. This hints that their contours are not defined by antithesis of level, while that of the northern coast of the great diaphragm is. Difference of altitude is then concerned in their constitution; the canal system here falls to a lower level, and these triangular spots instead of round ones are the result. Topographic only, such explanation leads the way to a more teleologic one, and serves even on first acquaintance to stir curiosity to some satisfying cause.

Suggestive in several ways for its resemblance to the carets is another detail not far distant from the Portus Sigaei, the twin-forked Sabaeus Sinus. Curiously enough, this feature of Mars, which has been well known and recognized ever since the eagle-eyed Dawes detected it more than forty years ago, proves to be a sort of connecting link between the main markings and the details of more modern detection. The twin-

forked Sabaeus Sinus, as its name implies, is of the form of a double bay; was considered to be one in fact so long as the *maria* were held to be seas. It straddles the point of land which, called the Fastigium Aryn, has been taken for the Greenwich of Martian longitudes. Each 'bay' — not in truth a bay at all — indents the ochre in an acute triangle, from the tip of which many canals proceed like the rays of a fan from a holding hand. Both tips are darker than the main body of the dark *mare* from which they proceed. They thus recall in general character the carets. They further reproduce specifically the Portus Sigaei, for they give origin to two doubles, the Gihon and the Hiddekel, in exactly the same manner that the two nicks of the Portus Sigaei do to the Phison and Euphrates. Nor are their tips much farther apart than those of the Portus, five degrees measuring the spread of the one and four degrees that of the other respectively; the reason for their earlier discovery lying in their greater size. They thus perform the same office as the Portus Sigaeus, are quite comparable to it in width, and differ in shape only as a larger and more acute triangle differs from a smaller and blunter one. Undreamt of by Dawes and unheeded since, they were the first hint to the world of the duality which forms so strangely pervasive a feature of the canal system of the planet.

Thus the carets stand connected with the canals

quite as intimately as the oases but in a significantly different manner. For, in addition to their intermediary standing between the light regions and the dark, their relation to the doubles is peculiar. An instance is offered by the double Euphrates and another by the Ganges. The Euphrates, as we saw in Chapter XVIII, leaves the Portus Sigaei at the south, one line leaving each caret centrally, so that each caret is concerned only with its own line and has no connection with its fellow. At their northern ends both lines have similarly each its own Lucus Ismenius. The like seems to be true of the Ganges. Similarly the twin Titan, have each its own. Such twin duty in the matter of doubles seems to be the rule with the carets, even more so than with the oases; and this is probably from the fact that the coastline is of more limited extent than the interior.

Altogether the carets offer to our inspection glosses in finer print upon the general text of the canals. Thought upon what they show takes us a step farther toward the solution of the strange riddle of this other world, a riddle which he who runs may not read, still less scout, and which only reasoning, without prejudice or partiality, can unravel.

CHAPTER XXII

THE CANALS PHOTOGRAPHED

PHOTOGRAPHY holds to-day a place of publicity in the exposition of the stars. Directed by Draper to the heavens thirty-four years ago, the camera recorded then the first picture ever taken of the moon. From this initial peering into celestial matters, practice has progressed until now the dry plate constitutes one of the most formidable engines in astronomic research. Not most effectively, however, in the field which might have been predicted. Beautiful as the lunar presentment was, as a presentiment of what was coming, it pointed astray. For it is not in lunar portrayal, superbly as its crater walls in crescent chiaroscuro or its crags that cast their tapering shadows athwart the dial of its plains stand out in the latest photographs of our satellite, that the camera's greatest service has since been done. Impressive as they are, these pictorial triumphs are chiefly popular, and appeal on their face to layman and scientist alike. Not in the nearest to us of the orbs of heaven, but in the most remote has celestial photography's most prolific field been found to lie. Its province has proved preëminently the stars,

especially the farthest off, and that star-dust, the nebulæ, from out of which the stars are made. Reason for this explains at once its efficiency and its limitations.

Its rival, of course, is the eye. It is as regards the eye that its comparative merits or demerits stand to be judged. Now, thus viewed, its superiority in one respect is unquestionable; it simply states facts. But though it cannot misinform, it can color its facts by giving undue prominence to the effect of some rays and suppressing the evidence of others, so that its testimony is not, it must be remembered, always in accord with that of human vision. Speaking broadly, however, it is so little complicated a machine as to register its results with more precision than the retina. The evidence of the camera has thus one important advantage over other astronomic documents: it is impersonally trustworthy in what it states. Bias it has none, and its mistakes are few. Imperfections, indeed, affect it, but they are of purely physical occasion and may be eliminated or accounted for as well by another as by the photographer himself.

In trustworthiness, then, so far as it goes, it stands commended; not so much may be said of its ability. This depends upon the work to which it is put. In certain lines it asserts preëminence; in certain others it is so far behind as to be out of the race. The reason for both is one and the same, for, as the French would

say: It has the faults of its quality. The very trait that fits it for one function, bars it from the other. This excellence is that by which the tortoise outstripped the hare, — a plodding perseverance. Far less sensitive than the retina the dry plate has one advantage over its rival, — its action is cumulative. The eye sees all it can in the twentieth of a second; after that its perception, instead of increasing, is dulled, and no amount of application will result in adding more. With the dry plate it is the reverse. Time works for, not against it. Within limits, themselves long, light affects it throughout the period it stands exposed and, roughly speaking, in direct ratio to the time elapsed. Thus the camera is able to record stars no human eye has ever caught and to register the structure of nebulæ the eye tries to resolve in vain.

Where illumination alone is concerned the camera reigns supreme; not so when it comes to a question of definition. Then by its speed and agility the eye steps into its place, for the atmosphere is not the void it could be wished, through which the light-waves shoot at will. Pulsing athwart it are air-waves of condensation and rarefaction that now obstruct, now further, the passage of the ray. By the nimbleness of its action the eye cunningly contrives to catch the good moments among the poor and carry their message to the brain. The dry plate by its slowness is impotent to

follow. To register anything, it must take the bad with the better to a complete confusion of detail. For the air-waves throw the image first to one place and then to another, to a blotting of both.

All of which renders the stars, where lighting counts for so much and form for so little, the peculiar province of celestial photography. With the study of the surfaces of the planets the exact contrary is the case. With most of them illumination is already to be had in abundance; definition it is that is desired. What succeeds so excellently with the stars is here put to it to do anything at all. At its best, the camera is hopelessly behind the eye when it comes to the decipherment of planetary detail. To say that the eye is ten times the more perceptive is not to overstep the mark. To try, therefore, here to supplant the eye by the camera is time thrown away.

Of scant importance to the expert in such matters as Mars, there is a side of the subject in which service might be hoped of it: that of elementary exposition. Congenitally incapable of competing with the eye in discovery, the most that, by any possibility, could be looked for would be a recording of the coarser details after the fact. For this reason it had long been a purpose at Flagstaff to photograph some at least of the canals. But the project seemed chimerical. To get an image suitable at all some seconds of exposure

would be required, and during such time the shifting air-waves would blur the very detail desired to be got. It was a problem of essential premises mutually annihilative. The more the would-be photographer should avoid the one, the more he would fall into the other.

Nevertheless the thing was tried in 1901. In 1903 the subject was taken up by Mr. Lampland, then new at the observatory. The results were better than those of two years before, the images more clear-cut but still incommunicable of canals. Still they were satisfactory enough to spur to increased endeavor, and during the following interopposition preparations were made to grapple with the planet as successfully as could be devised at its next return. This happened in May, 1905. It then showed a disk only 17″ in diameter, or $\frac{1}{120}$ of that of the moon, — and this disk Mr. Lampland attacked with the 24-inch and a negative amplificator that increased the focal length of the former to 143 feet. At such focus the planet's image was received upon the plate. Everything that could conduce to success had been put in requisition. To this end of better definition the color curve of the objective was first got, and for it a special color screen constructed by Wallace. In spite of its name no achromatic is so in fact, but brings rays of different tint to different focus. The color curve shows where these severally lie, and the color screen, a chemically tinted

piece of glass, is to absorb all those which would blur the image by having a different focus from the ones retained. Next, all manner of plates were tried. For in these again it was necessary to reconcile two contradictory characters, a rapid plate and a well-defining one. For the coarser the grain the speedier the plate; and coarse grain disfigures the detail. Both qualities on so small an image were obligatory and yet both could not be got. Then the clock had to be as smooth-running as possible. So by a suggestion of Mr. Cogshall's one was obtained that filled this requisite, a new form of conical pendulum. Upon this a further refinement was practiced. Ordinarily clockwork is timed to follow the stars; this was altered to follow the planet, and so keep it more nearly motionless while its picture was being taken. Then the device of capping down the telescope to suit the air-waves, which had been found so effective to the bringing out of fine detail, was put in practice. Lastly, all developers were tried, and those found suited to the finest work were used.

Many pictures were taken on each plate one after the other, both to vary the exposure and to catch such good moments as might chance. Seven hundred images were thus got in all; the days of best definition alone being utilized. The eagerness with which the first plate was scanned as it emerged from its last bath may

be imagined, and the joy when on it some of the canals could certainly be seen. There were the old configurations of patches, the light areas and the dark, just as they looked through the telescope, and never till then otherwise seen of human eye, and there more marvelous yet were the grosser of those lines that had so piqued human curiosity, the canals of Mars. He who ran might now read, so that he had some acquaintance with photography. By Mr. Lampland's thought, assiduity, and skill, the seemingly impossible had been done.

After the initial success was thus assured, plates were taken at other points around the planet and other well-known features came out; "continents" and "seas," "canals" and "oases," the curious geography of the planet printed for the first time by itself in black and white. By chance on one of the plates a temporal event was found registered too, the first snowfall of the season, the beginning of the new polar cap, seen visually just before the plate happened to be put in and reproduced by it unmistakably. Upon the many images thirty-eight canals were counted in all, and one of them, the Nilokeras, double. Thus did the canals at last speak for their own reality themselves.

PART III

THE CANALS IN ACTION

CHAPTER XXIII

CANALS: KINEMATIC

SO far in our account of the phenomena we have regarded the lines, the spots, and everything that is theirs solely from the point of view of their appearance at any one time. In other words, we have viewed them only from a static standpoint. In this we have followed the course of the facts, since in this way were the canals first observed. We now come to a different phase of the matter, — the important disclosure, with continued looking, that these strange things show themselves to be subject to change. That is, they take on a kinematic character. This at once opens a fresh field of inquiry concerning them and widens the horizon of research. It increases the complexity of the problem, but at the same time makes it more determinate. For while it greatly augments the number of facts which must be collected toward an explanation of what the things are, these once acquired, it narrows the solution which can apply to them.

The fact of change in the Martian markings forces itself upon any one who will diligently study the planet. He will be inclined at first to attribute it to observa-

tional mistakes of his own or his predecessor's making, preferably the latter. But eventually his own delineations will prove irreconcilable with one another, and he will then realize the injustice of his inference and will put the cause, where indeed it rightly belongs, on the things themselves. Confronted by this fact he will the more fully appreciate how long and systematic must be the study of him who would penetrate the planet's peculiarity. Just as the recognition of something akin to seasonal change came to Schiaparelli, because of his attending to the planet with an assiduity unknown to his predecessors; so it became evident that to learn the laws of these changes and from them the meaning of the markings, there was necessary as full and as continuous a record of them as it was possible to obtain. For this end it was not enough to get observations from time to time, however good these might be, but to secure as nearly as might be a complete succession of such, day after day, month after month, and opposition after opposition. The outcome justified the deduction. And it is specially gratifying to realize that to no one have the method and the results thus obtained appealed with more force than to Schiaparelli himself.

Perseverance in scanning the disk long after the casual observer had considered it too far away for observational purposes, resulted in Schiaparelli's detec-

tion of the canals, and this through a characteristic of theirs destined to play a great part in their history, their susceptibility to change. He tells us in his *Memoria I* how Aeria and the adjoining regions showed blank of any markings while the planet was near in 1877 and the disk large and well shown, and then how, to his surprise, as the planet got farther away and the disk shrank, lines began to come out in the region with unmistakable certainty. Thus to the very variability which had hidden them to others was due in Schiaparelli's hands their initial recognition.

Flux affecting the canals was apparent from the outset of my own observations. No less the subject of transformation than the large dark regions was the network of tenuous lines that overspread them. At times they were very hard to make out, and then again they were comparatively easy. Distance, instead of rendering them more difficult, frequently did the reverse. Nor was the matter one of veiling. Neither our own atmosphere nor that of Mars showed itself in any way responsible for their temporary disappearance. It was not always when our atmospheric conditions were best that the lines stood out most clearly, and as to Martian meteorology there was no sign that it had anything whatever to do with the obliteration. Long before the canals were dreamt of, veiling by Martian clouds or mist had been considered the cause

of those changes in the planet's general features, which are too extensive and deep-toned wholly to escape observation even though none too clearly seen. It was early evident to me that they were not the cause of general topographic change, and equally clearly as inoperative in those that affected the canals. In short, nothing extrinsic to the canal caused its disappearance; whatever the change was, its action lay intrinsic to the canal itself.

On occasion canals in whole regions appeared to be blotted out. The most careful scrutiny would fail to disclose them, where some time before they had been perfectly clear. And this though distance was at its minimum and definition at its best. Even the strongest marked of the strange pencil lines would show at times only as ghosts of their former selves, while for their more delicate companions it taxed one's faith to believe that they could ever really have existed. Illumination was invoked to account for this, and plays a part in the effect undoubtedly. For at plumb opposition the centre of the disk for two or three years has shown less detail than before and after that event. This is probably due not, as with the moon, to the withdrawal of shadows, but to the greater glare to which the disk is then subjected. But this is not the chief cause of the change.

Still more striking and unaccountable was the fact

that each canal had its own times and seasons for showing or remaining hid. Each had its entrances upon the scene and its exits from it. What dated the one left another unaffected. The Nilokeras was to be seen when the Chrysorrhoas was invisible, and the Jamuna perfectly evident when the Indus could scarcely be made out.

Showing seasonal change.
I.

So much shows in the two drawings here reproduced. The increase of the Ganges and the advent of the Chrysorrhoas are noticeable in the second over the first.

Showing seasonal change.
II.

Seasonal changes seemed the only thing to account for the phenomena. And in a general sense this was undoubtedly the explanation. To learn more about the matter, to verify it if it existed, and to particularize it if possible, I determined to undertake an investigation permitting of quantitative precision in the case. A method of doing this occurred to me which would

yield results deserving of consideration from the amount of data upon which each was based and capable of being compared with one another upon an equal footing from which relative information could be derived. It seemed wise to determine from the drawings the degree of visibility of a given canal at different seasons of the Martian year, and then to do this for every important canal during the same period of time. The great number of the drawings suggested this use to which they might be put. For from a great accumulation of data a set of statistics on the subject could be secured in which accident or bias would be largely eliminated and the telling effect of averages make itself felt.

To render this possible it was necessary that the drawings should be alike numerous, consecutive, and extended in time. These conditions were fulfilled by the drawings made by me at the opposition of 1903. Three hundred and seventy-two drawings had then been secured, and they covered between them a period of six months and a half. They were also as consecutive as it was possible to secure. During a part of the period the planet was seen and drawn at every twenty-four hours, from April 5, namely, to May 26, or for forty-six consecutive days. Though the rest of the time did not equal this perfection, no great gap occurred, and one hundred and forty-three nights were utilized in all.

Furthermore, as these drawings were all made by one man, the personal equation of the observer — a very important source of deviation where drawings are to be compared — was eliminated.

But even this does not give an idea of the mass of the data. For by the method employed about 100 drawings were used in the case of each canal, and as 109 canals were examined this gave 10,900 separate determinations upon which the ultimate result depended. That each of these determinations was independent of the others will appear from a description of the method itself on which the investigation was conducted. To understand that method one must begin a little way back.

As the two planets, Mars and the Earth, turn on their axes the parts of their surfaces they present to each other are constantly changing. For a feature on Mars to be visible from a given post on earth, observer and observed must confront each other, and, furthermore, it must be day there when it is night here. But, as Mars takes about forty minutes longer to turn than the Earth, such confronting occurs later and later each night by about forty minutes, until finally it does not occur at all while Mars is suitably above the horizon; then the feature passes from sight to remain hidden till the difference of the rotations brings it round into view again. There are thus times when a given region

is visible, times when it is not, and these succeed each other in from five to six weeks, and are called presentations. For about a fortnight at each presentation a region is centrally enough placed to be well seen; for the rest of the period either ill-placed or on the other side of the planet.

If a marking were always salient enough it would appear in every drawing made of the disk during the recurrent fortnights of its display. If it were weaker than this, it might appear on some drawings and not on others, dependent upon its own strength and upon the definition at the moment, and we should have a certain percentage of visibility for it at that presentation. While if it changed in strength between one presentation and the next, the percentage of its recording would change likewise. Definition of course is always varying, but if its value be noted at the time of each drawing this factor may be allowed for more or less successfully. Making such allowance, together with other corrections to produce extrinsic equality, such as the planet's distance, which we need not enter upon here, we are left with only the marking's intrinsic visibility to affect the percentages; that is, the percentages tell of the changes it has successively undergone and give us a history of its wax and wane.

From drawings accurately made it is possible to add to the accuracy of the percentage by noting in each,

not only the presence or absence of the marking, but the degree of strength with which it is represented. This was done on the final investigation in the present case, and it was interesting to note how little difference it made in the result.

The longitude of each canal was known, and the longitude of the central meridian of each drawing was always calculated and tabulated with the drawing, so that it was possible to tell which drawings might have shown the canal. Only when the position of the canal was within a certain number of degrees of the centre of the drawing (60°) was the drawing used in the result, allowance being duly made for the loss upon the phase side. Each drawing, it should be remembered, was as nearly an instantaneous picture of the disk as possible. It covered only a few minutes of observation, and was made practically as if the observer had never seen the planet before. In other words, the man was sunk in the manner. Such mental effacement is as vital to good observation as mental assertion is afterward to pregnant reasoning. For a man should be a machine in collecting his data, a mind in coördinating them. To reverse the process, as is sometimes done, is not conducive to science.

When the successive true percentages of visibility of a given canal had thus been found, they were plotted vertically at points along a horizontal line correspond-

ing in distance from the origin to the number of days after (or before) the summer solstice of the Martian northern hemisphere. The horizontal distance thus measured the time while the vertical height gave the relative visibility. The points so plotted were then joined by a smooth curve. This curve reproduced the continuous change in visibility undergone by the canal during the period under observation. It gave a graphic picture of the canal's change of state. It seemed, therefore, proper to call it the canal's cartouche or sign manual.

In this manner were obtained the cartouches of 109 canals. Now, as the presence or absence of any canal in any drawing was entirely irrespective of the presence or absence of another, each such datum spoke only for itself, and was an entirely independent observation. The whole investigation thus rested on 10,900 completely separate determinations, each as unconditioned by the others as if it existed alone.

As every factor outside of the canal itself which could affect the latter's visibility was taken account of, and the correction due to it as nearly as possible applied before the cartouches were deduced, the latter represent the visibility of the canal *due to intrinsic change alone*. In other words, they give not the apparent only but the real history of the canal for the period concerned.

Important disclosures result from inspection of the cartouches. This we shall perceive by considering what different curves mean in the case. If the canal were an unchangeable phenomenon, for any reason whatever, its cartouche would be a *straight line parallel to the horizon* of the diagram. This is evident from the fact that the visibility would then never vary. If, on the other hand, it were waxing and waning, and the wax or wane were uniform, the cartouche would be a straight line *inclined to the horizontal;* rising if the canal were increasing, falling when it decreased. Lastly, if the rate of change itself varied, the cartouche would be a curve concave or convex to the line denoting the time, according as the rate of change of the growth or decay grew greater or less.

To see this the more clearly, we may set over against the cartouche the canal character it signalizes: —

CARTOUCHE.	CHARACTER.
A horizontal straight line.	Canal invariable.
A straight line tilted up on the right.	Canal increasing steadily.
A straight line tilted up on the left.	Canal decreasing steadily.
A curved line descending, concave from above.	Canal decreasing, but more and more slowly.
A curved line ascending, concave from above.	Canal increasing, but more and more rapidly.
A curved line descending, convex from above.	Canal decreasing more and more rapidly.
A curved line ascending, convex from above.	Canal increasing more and more slowly.

CARTOUCHE.	CHARACTER.
A curved line first descending, then ascending, concave from above throughout.	Canal decreasing more and more slowly to a minimum, thence increasing more and more rapidly.
A curved line first descending, then ascending, convex from above throughout.	Canal increasing more and more slowly to a maximum, thence decreasing more and more rapidly.

If the cartouche first falls and then rises, this shows the canal to have passed through a minimum state at the time denoted by the point of inflection; if it rises first and falls afterward, this betokens in the same way a maximum. Thus the cartouches reveal to us the complete history of the canals, — what changes they underwent and the times at which these occurred. The cartouche, then, is the graphic portrayal of the canal's behavior. It not only distinguishes at once between the dead and the living, as we may call the effect of intrinsic change, but it tells the exact character of this change, — the way it varied from time to time, the epoch at which the development was at its minimum or its maximum for any given canal, and lastly, its actual strength at any time, thus giving its relative importance in the canal system. For the height of the curve above the diagrammatic horizon marks the absolute as well as the relative visibility and enables us to rank the canals between themselves.

Now, the first point it furnishes a criterion for is the

real or illusory character of the canals. If a line be due to illusion, whether optical or physical, it can vary only from extrinsic cause, since it has no intrinsic existence. If, therefore, all extrinsic cause be allowed for, the cartouche of this ghost must needs be a *horizontal straight line.* Even if the extrinsic factors to its production be imperfectly accounted for, their retention could only cause systematic variations from the straight line in all the lines, which would themselves vary systematically, and these factors could therefore be detected.

This criterion is absolute. Unless all the cartouches were approximately straight lines, no illusion theory of any kind whatever could explain the facts. Even then the lines might all be real; for unchangeable reality would produce the same effect on the cartouches as illusion. In the case therefore of horizontal straight line cartouches, we should have no guarantee on that score of reality or illusion; but, on the other hand, curves or inclined straight lines in them would be instantly fatal to all illusion theories.

Turning now to the 109 cartouches obtained in 1903, the first point to strike one's notice is that all but three of them are curves and that even these three must be accepted with a caveat. Here, then, the cartouches dispose once and for all of any and every illusion theory. They show conclusively that the canals are real objects which wax and wane from some intrinsic cause.

The second result afforded by the cartouches is not of a destructive, negative character, — however valuable the destruction of bars to knowledge may be, — but of a constructive, positive one. It does not, like the first, follow from mere inspection, but is brought to light only by comparison of all the cartouches. In a positive way, therefore, its testimony is as conclusive as it was in a negative direction. For that 10,900 separate and independent data should result in a general law of development through either conscious or unconscious bias, when those data would have to be combined in so complicated a manner for the result to emerge as is here the case, is impossible. Chance could not do it and consciousness would require a coördinate memory, to which Murphy's nine games of chess at once would be child's play.

Of the 109 canals examined 106 showed by their cartouches that they had been during the whole or a part of the period in a state of change. But the change was not the same for all. In some the minimum came early; in others, late. Some decreased to nothing and stayed there; others increased from zero and were increasing still at the time observations closed.

Latitude proved the means of bringing comparative order out of the chaos. When the canals were ranged according to their latitude on the planet, a law in their development came to light. To understand it, the circumstances under which the canals were presented

must be considered as regards the then season of the planet's year. In 1903 the planet passed on February 28 through the point of its orbit where the summer solstice of the northern hemisphere occurs. One hundred and twenty-six days later took place the first snowfall in the arctic and subarctic regions, an event that denoted the beginning of the new polar cap; from which date the snow there gradually increased. Its autumnal equinox the planet did not reach till August 29. Now, the canals were observed from thirty-six days before the summer solstice of the northern hemisphere to one hundred and forty-seven days after that event. We may tabulate the dates as follows: —

Day from Summer Solstice	Vernal Longitude	Corresponding Date on Earth
− 30	77°	June 9
0	90°	June 22
+ 30	103°	July 6
+ 60	117°	July 20
+ 90	131°	August 4
+ 120	146°	August 20
+ 150	162°	September 5

The vernal longitude is the longitude of the planet in its orbit reckoned from the vernal equinox. From the table it appears that the cartouches cover the development of the canals from about June 6 to September 1 of the Martian northern hemisphere for the current but to us undated year, *ab Marte condita.*

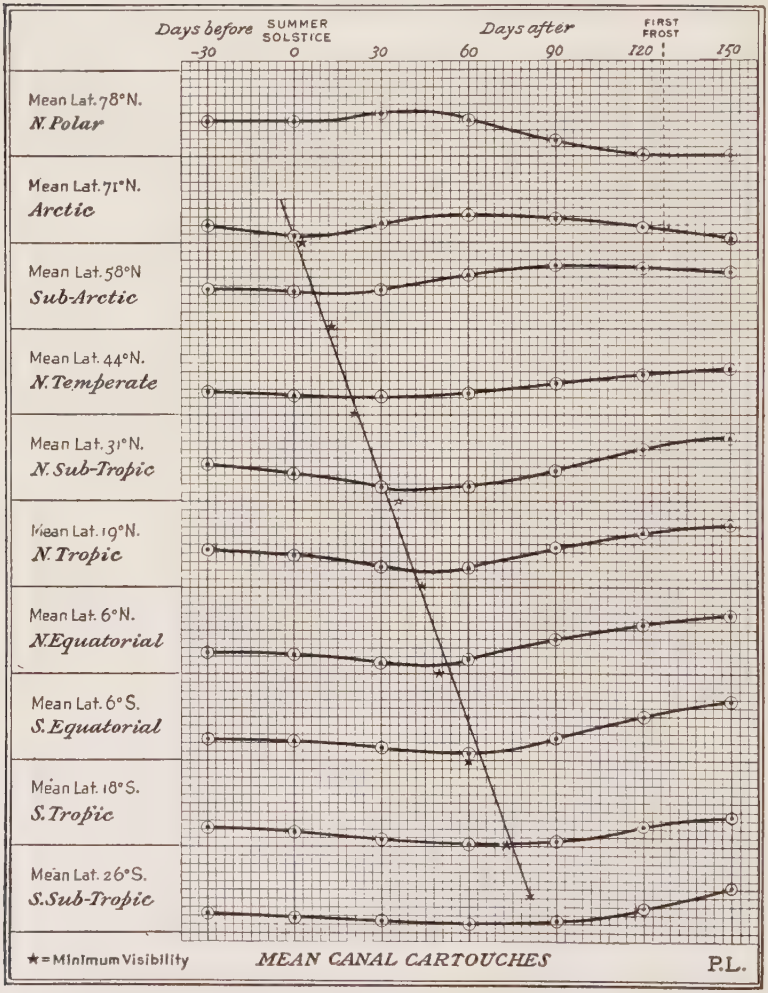
The 109 canals included all the more conspicuous canals on the planet at that opposition, all those that lent themselves by the sufficient frequency with which they were seen to a statistical result. They lay spread all the way between the edge of the polar cap in latitude 87° north to the extreme limit south, at which the then tilt of the north pole toward the earth permitted of canal recognition. This southern limit was in about latitude 35° south. Farther south than this vision became too oblique, amounting as it did, with an adverse tilt of twenty-five degrees to start with, to something over sixty degrees, for detection of such fine markings to be possible. Between the two limits thus imposed, by the perpetual snow on the one side and the observational tilt on the other, the 109 canals were distributed by zones as follows: —

Zone	Latitude	Number of Canals
North Polar	87° N.–78° N.	1
Arctic	78° N.–66° N.	9
Sub-Arctic	66° N.–51° N.	9
North Temperate	51° N.–37° N.	11
North Sub-Tropic	37° N.–24° N.	18
North Tropic	24° N.–12° N.	21
North Equatorial	12° N.– 0° N.	14
South Equatorial	0° N.–12° S.	17
South Tropic	12° S.–24° S.	7
South Sub-Tropic	24° S.–37° S.	2

As the latitude of a canal in the investigation was taken as that of its mid-point, such being the mean value of its successive parts, the latitudes about which information was obtained lay within the limits given above, the most northern canal, the Jaxartes N having for its mid-latitude 78° north, and the most southern, the Nectar, that of 27° south.

The zones comprised each a belt of territory about thirteen degrees wide, the first being less solely because in part occupied by the permanent polar cap.

The curves of all the canals in a given zone have been combined into a mean curve or cartouche for that zone; and then the cartouches for the several zones have been represented and ranged according to latitude on the accompanying plate. Consideration of these mean canal cartouches is very instructive. In the first place not one of them is a straight line, either horizontal or inclined. All are curves and, with the exception of the top one, all show a minimum or lowest point during the period under observation. From this point they rise with the time, or to the right on the plate. A black star marks this minimum, and is found farther and farther to the right as one goes down the plate; that is, as one travels from the neighborhood of the arctic regions down to the equator and then over into the planet's southern hemisphere. Drawing now a line approximately through the stars and remembering


Days before
SUMMER SOLSTICE
Days after
FIRST FROST
-30
0
30
60
90
120
150
Mean Lat. 78°N.
N. Polar
Mean Lat. 71°N.
Arctic
Mean Lat. 58°N
Sub-Arctic
Mean Lat. 44°N.
N. Temperate
Mean Lat. 31°N.
N. Sub-Tropic
Mean Lat. 19°N.
N. Tropic
Mean Lat. 6°N.
N. Equatorial
Mean Lat. 6°S.
S. Equatorial
Mean Lat. 18°S.
S. Tropic
Mean Lat. 26°S.
S. Sub-Tropic
★ = Minimum Visibility
MEAN CANAL CARTOUCHES
P.L.

that the minimum means the date at which the canal started to develop, we see that the canal development began at the border of the north polar cap and thence continued down the disk over the planet's surface, as far as observation permitted the surface to be seen, which was some thirty-five degrees into the other hemisphere. This is the first broad fact disclosed by the cartouches.

Furthermore, the development took place at an approximately uniform rate. This is shown by the fact that the line passing through the black stars is approximately straight; for such straightness means that progression down the disk as measured by the latitude bore throughout the same ratio to the time elapsed.

Looking at them again we notice that the three topmost cartouches, those of the north polar, arctic, and sub-arctic canals respectively, dip at the right before the end of the observations, while the other seven were still rising when those observations were brought to a close. A reason for this, or at least a significant coincidence, is to be found in the dotted line pendent from the top of the table and labelled "First Frosts." This dotted line denotes the date at which the first extensive frost occurred in the polar regions; for even before this time patches of white had appeared north of the Mare Acidalium, denoting the on-coming of the cold.

The frost did not last but came and went and came again just as it does on earth, growing more insistent and long-lived at each fresh fall. Its sphere of operation was confined to the three zones in question. Even these zones it by no means covered, merely blotching them in places with fungi-like patches of frost. Beyond them south it never extended during the period of the observations; indeed, it hardly entered the subarctic zone at all at this very beginning of the polar winter. For it was only August 20 then. The coincidence of the isotherm as betrayed by the deposition of frost with the dividing line between the canal-development curves that dip down at this season and those that still continue to rise is suggestive.

It becomes all the more so when the three cartouches are considered seriatim. The most polewards, the north polar one, had sunk to zero sometime before the first extensive frost occurred; the second, the arctic, did so later than its northern neighbor, probably just before the epoch in question; while the third, practically outside the zone of deposition, was behind both the others in its descent. Inspection of the drawings upon which the cartouches are based confirms an inference deduced from this: that it was cold that killed, not frost that covered, them, which was responsible for their obliteration. The drawings show that the canals ceased to be seen before the white patches were

evident. Now this would be the exact behavior of vegetation. It would be killed, turned brown by freezing, and so rendered invisible to us against its ochre desert background, before the cold had grown intense enough to cover that ground with a solid white carpet of frost. At the opposition of 1905, however, the extreme northern canals were visible after the snow had covered all the country about them, being evident as lines threading the new cap.

These three cartouches furthermore show each a maximum, and what is significant the maximum occurs later in time for each, according as the zone lies remote from the pole. A red star marks this maximum and shows that the time of greatest development for the three zones was respectively: —

41 days after the summer solstice for the North Polar.
61 days after the summer solstice for the Arctic.
95 days after the summer solstice for the Sub-Arctic.

We now pass to the other curves, those that were unaffected by cold. Though in these the minima themselves show the law of latitudinal progression, the wave-like character of the advance is even better disclosed by the curves. As the eye follows them down the page, the advance of the wave to the right is plainly apparent. The slope of the wave is much the same for all, implying that a like force was at work successively down the latitudes.

It will be noticed next that in all the mean cartouches the gradient is greater after the minimum than before it. The curves fall gently to their lowest points and rise more steeply from them. Such profile indicates that the effects of a previous force were slowly dying out down to the minimum and that then an impulse started in to act afresh. This explains the attitude of the canals that died out. In them the effect of the old force shows as in the others, but no impulse came in their case to resuscitation.

It seems possible to trace this force to an origin at the south. For beginning with the north sub-tropic zone the gradient on the left shows less and less steep southward to the south sub-tropic zone. Such a dying-down swell is what should be looked for in an impulse which had travelled from the south northward, since the wave would affect the more northern zones last, and less of a calm period would intervene between the two impulses from opposite poles.

The cartouches, then, state that the canals began to develop after the greatest melting of the polar cap had occurred; that this development proceeded down the latitudes to the equator, and then not stopping there advanced up the latitudes of the other hemisphere. In the next place they show that in the arctic region the development was arrested and devolution or decay set in as it began to get cold there,

the most northern canals being affected first. Finally, that a similar wave of evolution had occurred from the opposite pole some time before and had then passed away. And this evidence of the cartouches is direct, and independent of any theory.

CHAPTER XXIV

CANAL DEVELOPMENT

Individually Instanced

AS an interesting instance of the law of development we may take the career of the Brontes during this same Martian year; the Brontes witnessing individually to the same evolutionary process that the canals collectively exhibit.

The Brontes is one of the most imposing canals upon the planet. It is not so much its length which renders it a striking object, though this length is enough to entitle it to consideration, being no less than 2440 miles. Its direction is what singles it out to notice, for it runs almost north and south. For this reason it swings into a position to hold the centre of the stage for a time with the precision of a meridian, as the planet's rotation turns its longitude into view. The points which it connects help also to add to its distinction. For the Sinus Titanum at its southern end and the Propontis at its northern are both among the conspicuous points of the disk. The latter is but twelve degrees farther east than the former, while it is sixty-six degrees farther north. This long distance, — from nearly the line of the tropics in the southern hemisphere to mid-temperate

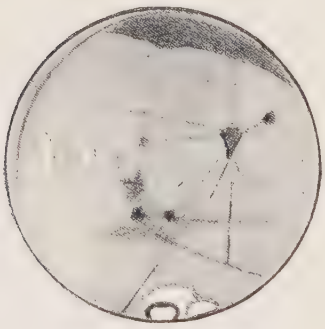
regions of the northern, — the canal runs in an absolutely straight course.

Its north and south character commends it for any investigation of canal development, since it runs in the general direction that development takes. Its great latitudinal stretch further fits it for a recorder of changes sweeping down the disk; so that both in direction and length it stands well circumstanced for a measure of latitudinal variations. The fact that it is usually a fairly conspicuous canal does not detract from its virtue in this respect. It was first recognized at Flagstaff in 1894. But once realized, so to speak, it was possible to identify it with a canal seen by Schiaparelli and supposed by him to be the Titan; indeed, it played hide and seek with that canal throughout his drawings. In 1894 both it and the Titan were so well seen that its separate existence was unmistakable, causing it to be both recognized and named. It is, like the Titan, one of the sheaf of canals descending the disk from the Sinus Titanum, and lies just to the east of the Titan in the bunch. In 1896 it was also prominent; and at both these oppositions most so from its southern end, its northern one being more or less indefinite, especially in 1894.

In 1901 it was not the same. Instead of being the conspicuous canal it had been in earlier years, it was now so faint as with difficulty to be made out. It

remained so to the close of observations. It was now under suspicion. Its behavior in 1896-1897 had led to the supposition that not only were seasonal changes taking place in it, but that those changes were such as to point to a law in the case with which its conduct in 1901 fayed in. The suspicion did not, however, become a certainty till the opposition of 1903. The length of time during which the disk was then kept under scrutiny resulted in the method of its metamorphosis being discovered.

At the very start of observations its longitude chanced to be nearly central and it was made out; but so far off was the planet that only its northern part could be detected, because, as afterward appeared, this part was the stronger, the canal being decidedly inconspicuous, whereas other canals, the northern and even the Pallene and the Dis, were strongly marked. At the next presentation the planet was nearer, and details previously hidden for the distance now came out. Among them was the Brontes, which, showing better than in January, could be traced all the way to the Sinus Titanum. A drawing (I) made on February 25

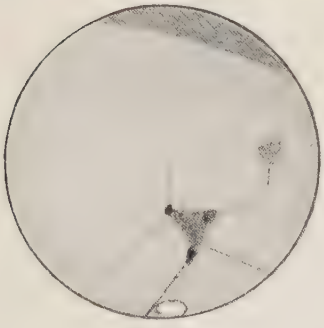


I. February 25.

and reproduced in the text shows its appearance at the time. Its emergence under neared conditions only served to accentuate its relative inconspicuousness, for it showed now notably inferior to the northern canals, and this not only in the matter of general visibility, but in the character it displayed. It was a line of hazy definition, contrasting thus with the sharp dark forms of its northern neighbors.

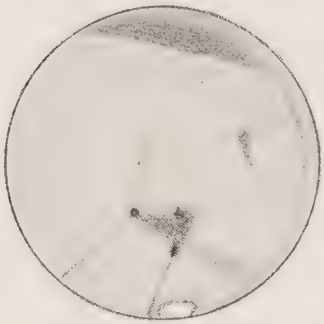
II. March 30.

As the planet steadily approached the earth, and the canals to the north became better and better seen, the Brontes instead of sharing in the general improvement did exactly the opposite. It grew less visible when it should have grown more so, if distance had been the cause of its appearance. It was now only to be seen at the north, even when it was seen at all; a state of things exemplified in Drawings II and III.

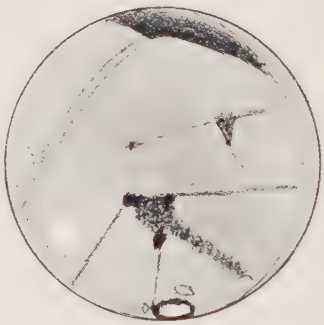


III. April 3.

As the planet now went away and detail should have dimmed, the Brontes proceeded to do the opposite. One had almost said it was actuated by a spirit of contrariety. For now when it had reason to grow faint it grew in conspicuousness; just as, before, when it should have become evident, it had declined. Distinctly farther off and smaller as the planet was at the next presentation, the Brontes had clearly developed both in tone and in the amount of it visible. This was in May (Drawings IV and V). In June bad seeing prevented good observations, but in July, Drawing VI, when the region again came round, the Brontes, in spite of the then greatly increased distance, asserted itself so strongly that even in not very good seeing its presence could not be passed by.



IV. May 4.



V. May 7.

This contrariety of behavior had about it one very telling feature. That the canal waxed or waned in exact

opposition to distance and even toward the last to seeing too, showed conclusively that neither distance nor definition could in any way be held responsible for its metamorphoses. A very fortunate circumstance, this of the observations, for it directly eliminated size of disk, phase, and seeing, for which correction are none too easy to make, and which in the minds of the sceptical could always remain as unexplained possibilities of error.

VI. July 18.

The mean-canal cartouches show synthetically, and all the more conclusively for being composite, the laws of the flux of the canals. Something more of vividness, however, is imparted by the actual look of one of the constituents during the process. It is the difference between seeing a composite picture made from a given group of men and the gazing on the actual features of any one of them. So much is gained by the drawings across the page of the Brontes at different stages of its evolution during the period here concerned. But in another way, too, the one canal may be made to yield a more lifelike representation of the process than a number taken together are capable of affording. In the mean-canal cartouches each canal is treated as an

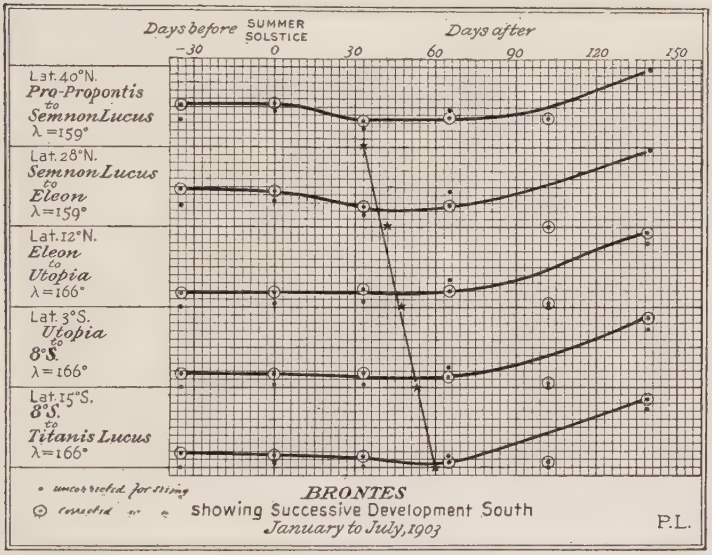
entity; but it is possible to consider a canal by parts, and by so doing to see it in action, as it were. It occurred to me to treat the Brontes in this way. For this purpose I divided the canal into sections, five of them in all, between the point where it left the Propontis, at a spot called the Propropontis, to where it ended in the Sinus Titanum. The first, the most northern, extended as far as Semnon Lucus, the southernmost outpost of the Propontis congeries of spots. The second continued on from these to Eleon, the junction where the Erebus crossed. The third thence to Utopia, where the canal met the Orcus; the fourth to an arbitrary point in latitude 8° south, and the fifth and last to the Sinus Titanum. The lengths of these sections were respectively: 12°, 16°, 15°, 12°, and 13°. Each of the sections was then treated as if it were a separate canal and its cartouche found. To the cartouches' determination there were available drawings:

January 21–25	12 drawings.
February 23–March 2	15 drawings.
March 28–April 5	14 drawings.
April 26–May 8	27 drawings.
June 3–16	6 drawings.
July 11–21	16 drawings.
	90 drawings in all.

The cartouches are given in the plate opposite, which is constructed precisely like the one for the mean

canal cartouches presented on page 298. The mid-latitude of the section and its mid-longitude are given in the margin with its description.

Examining them now we note a family resemblance between the successive cartouches. All sink slowly



on the left to rise sharply from their lowest point to the right. Such resemblance betokens the action of one and the same cause.

Next, although the curves are resemblant, each has been, as it were, sheered to the right as one reads down; that is, the action took place later and later as the latitude was north.

Lastly, the dying out of a previous impulse can be

traced in the cartouches, which shows that the canals were quickened six months previously from the south polar cap, as they were now being quickened from the north polar one.

CHAPTER XXV

HIBERNATION OF THE CANALS

CONNECTED with the conduct of the canals is a phenomenon, examples of which were early noted in a general way by Schiaparelli and later, but of which the full import and exhibition only came to light during the opposition of 1903 by a very striking metamorphosis: what may be called the hibernation of a canal for a longer or shorter term of years. What observation discloses is certainly curious. For several successive oppositions a canal will be seen in a definite locality, as regular in seasonal recurrence as it is permanent in place, a well-recognized feature of the disk. Then to one's surprise, with the next return of the planet, it will fail to appear, and will proceed to remain obliterate without assignable cause for many Martian years, until as unexpectedly it will be found what and where it was before. Neither to deposition of hoarfrost, such as frequently whitens whole regions of Mars, nor to other circumstances can be attributed its disappearance. Without apparent reason it simply ceases to be and then as simply comes back again.

Such bopeep behavior is quite beyond and apart from the seasonal change in visibility, to which all the canals are by their nature subject. For being creatures of the semi-annual unlocking of the water congealed about the polar caps, they quicken into growth and visibility, each in its season, and as regularly die out again. Different, however, is the phenomenon to which I now refer. In it not a seasonal but a secular change is concerned. The season proper to the canal's increase will recur in due course, and the canals round about it will start to life, yet the canal remains unquickened. Nothing responds where in years the response was immediate and invariable. The canal lies dormant spite of seasonal solicitation to stir.

Such curious hibernation was early hinted to the keenness of Schiaparelli, and most incomprehensible as well as difficult of verification at that stage the phenomenon was. That the absence was a fact, however, he assured himself, although he was not able to prove an alibi. But at the last opposition an event of the sort occurred which, from the length of time the planet was kept under observation, combined with continued suitableness of the seeing, unmasked the process. In the light of what then happened, taken in connection with the side-lights thrown upon it by the canal's past and by the knowledge we have meanwhile gained of the planet's physical condition, the riddle of the phenome-

non may in part at least be read, and most interesting and instructive the reading proves to be.

Among the initial canals detected by Schiaparelli, in 1877, was a tricrural set of lines recalling the heraldic design of three flexed legs joined equiangularly above the knees. It lay to the east of the Syrtis Major, and he called its three members the Thoth, the Triton, and the Nepenthes. Starting from the head of his gulf of Alcyonius, at a point now known to be occupied by the oasis called Aquae Calidae, the Thoth started south inclining westward as it went, till in longitude 267° and latitude 15° north, it met the Triton, which had come from the Syrtis Minor with similar westward inclination. To the same point in the same manner came the Nepenthes. Part way along the course of the latter was to be seen a small dark spot, the Lucus Moeris, which he estimated at four degrees in diameter. Some of the markings were easier than others, the easiest of all being the Lucus Tritonis, a largish dark spot at the common intersection of all three canals; but that none of the markings were remarkably difficult is sufficiently shown by their detection at this early stage of Schiaparelli's observations. It is worth noting also that he discovered the southern ones first; the Thoth not being seen till March, 1878. As his then recognition of these canals witnesses, they must have been among the most evident on the disk. And the

point is emphasized by the fact that he failed at this opposition to detect the Phison and the Euphrates as separate markings.

Much the same the three canals appeared to him at the next opposition of 1879, the Thoth being seen at its several presentations from October 5, 1879, to January 11, 1880.

At the next opposition a noteworthy alteration occurred, the full significance of which escaped recognition. Schiaparelli saw, at the place where the Thoth had been, two lines which he took for a gemination of that canal, one of which followed the course of the old Thoth, while the other went straight from the Sinus Alcyonius to the Little Syrtis, or, more precisely, to the junction of the Triton and the Lethes. It was not the Thoth, however, but something unsuspected, of more importance.

In 1884 the Thoth showed really double, the western line being much the stronger, "una delle piu grosse linee que si vedessero sul disco." That neither branch went farther than the meeting-place with the Nepenthes argues that it was indeed the Thoth that was seen. Schiaparelli himself had no doubt on the subject, although he drew the double canal he saw due north and south from the tip of the Sinus Alcyonius to the junction, but nevertheless along the 263° meridian.

In 1886 and 1888 the system was in all essentials,

what it had been in 1877 and 1879, except that the Thoth and Nepenthes were double and were more minutely seen.

Here, then, was a system of canals and spots which for six Martian years had been a persistent and substantially invariable feature of the Martian surface. Any changes in it had been of a secondary order of importance, while its general visibility was of the first. It is possible, then, to judge of my perplexity when in beginning my observations in 1894 no sign of the system could I detect. Of neither the Thoth, the Triton, the Nepenthes, nor the Lucus Moeris was there trace. And yet, from the other canals visible, it was evident that the disk was quite as well seen as it had been by Schiaparelli. Not only were practically all his canals there, but many much smaller ones were to be made out. And the same was true of the spots, a host of such not figured by him appearing here and there over the planet's surface.

Nor was this all. Instead of the Thoth, another canal showed straight down the disk from the Syrtis Minor to the Aquae Calidae. This canal was as unmistakable as the Thoth had been before to Schiaparelli. It was among the first to be detected, and continued no less conspicuous to the end, the dates at which it was seen being July 10, August 14, and October 21. I called it the Amenthes, identifying it with the canal so named

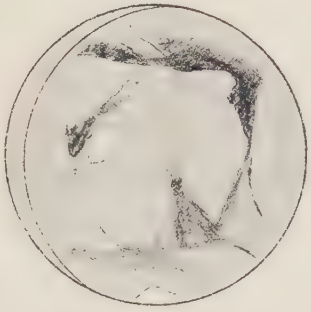
in Schiaparelli's chart published in *Himmel und Erde*, of the *ensemble* of his observations from 1877 to 1888. But in his Memoirs he never called it so, seeing it, indeed, only in 1881–1882, and deeming it then the Thoth. Nevertheless, in 1894, it was the conspicuous canal of the region, and, what is more, had come, as it proved, to stay.

The invisibility of the Thoth continued for me the same during the succeeding oppositions of 1896–1897 and 1901. At the former opposition I drew it in 1896 on July 28, August 26, September 2, October 5–9, seeing it single; and in 1897 on January 12–19, February 21, and March 1. It was single but with suspicions of doubling in January, and was indubitably double in February. As for the Thoth, I had come to consider it and the Amenthes one, attributing their diversity of depiction to errors in drawing. For while the Thoth remained obstinately invisible, the Amenthes presented itself as substitute so insistently as to make one of the most obvious canals upon the disk.

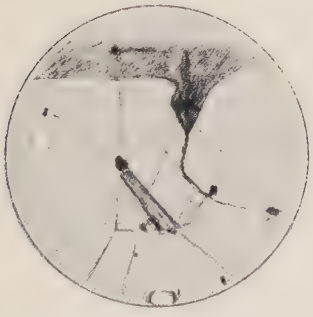
One exception only was there to this state of things. On June 16, 1901, my notes contain this adumbration of a something else: "Amenthes sometimes appeared with a turn to it two-thirds way up; two canals concave to the Syrtis Major."

So matters opened at the opposition of 1903. With the advent of the planet and the presentation in due

course of Libya in February, the Amenthes duly appeared, much as it had showed at the opposition before, only less salient. It was a confused and seemingly narrower double. Suspected on the 16th of that month, it was definitely seen from the 18th to the 23d. Of the Thoth no mention is made either in the notes or in the drawings. When the region came round again, in March, the Amenthes was still there, showing more feebly, however, than it had in February, in spite of better seeing and the fact that the planet had considerably neared. Clearly the canal was fading out; a fact further witnessed to by the following note made on March 25: "Throughout this opposition thus far the dark triangle tipped by Aquae Calidae has been sharply divided in intensity from the Amenthes, which is very narrow and exceedingly faint." Still was there no trace of the Thoth.

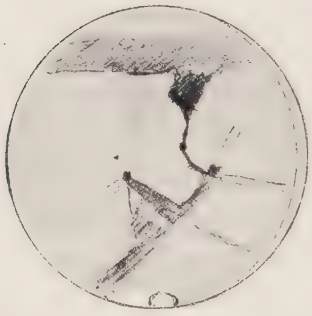


Amenthes alone in February.



Amenthes feebler and still alone in March.

With the April presentation entered a new order of things. When the region first became visible, on the 16th, the Amenthes could still be seen and alone; but on the 19th, as the relative falling back of the Martian longitudes swung the region nearer the centre of the disk, the Thoth appeared alongside of it. On the 20th the Thoth showed alone. Unmistakable it was and just as Schiaparelli had drawn it, accompanied by the Triton and the curved Nepenthes. The thing was a revelation. What before I had seen only in the spirit of another's drawings stood there patent to me in the body of my own; while the Amenthes, to which I had so long been accustomed, had vanished into thin air. Only a trace of it was now and then to be made out. So startlingly strange was the metamorphosis that I could not at first trust my eyes, and questioned the broken line, which had replaced the straight, for some ocular deception. But nothing I could do would rectify it. The Amenthes was gone and the Thoth stood in its stead.



Appearance of Thoth with Triton and curved Nepenthes. Amenthes vanished. April 20.

At the next presentation, May 26 to June 8, the phenomena were repeated, and with increasing clarity.

And then of a sudden, on May 29, I saw the long-given-up Lucus Moeris. There it was indubitably. And its definiteness was the most astonishing part of the affair. It was no question of difficult detection. Indeed, I had not been on the lookout for it, having searched the region too often fruitlessly before to have left incentive to search again. And so, when I was not searching, the thing of its own accord stepped forth to sight. It was a small round dot, like to any other oasis, and showed, as it were, a black pearl pendent by the Nepenthes from the Syrtis's ear. For the Libyan bay made a dark projection of the sort high up on the Syrtis's eastern side, from which the Nepenthes, precisely as Schiaparelli had drawn it, curved down to the point where the Thoth and Triton met. All three canals were geminated, the gemination being about three degrees wide.

Advent of the Lucus Moeris. May 29.

And now occurred the last act in the drama. In July the Amenthes reappeared, showing alongside of the Thoth-Nepenthes, and thus removing any possible doubt as to their separate identity. It had, indeed, become the stronger of the two, having gained in

strength in the interval between June and July and the Thoth-Nepenthes having lost. The lines were in process of relapsing into the *status quo ante*. Had these three presentations not been watched, the brief apparition of the Thoth-Nepenthes had been missed and with it the revealing of its curious character, and of certain deductions thereupon.

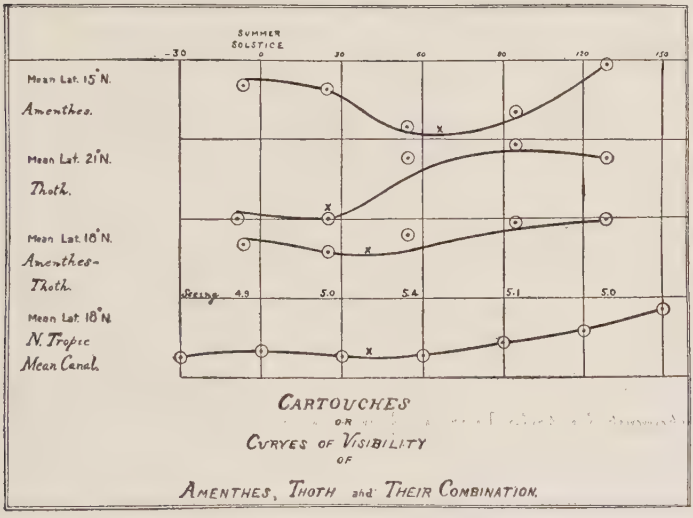
Amenthes with Thoth-Nepenthes. July.

First among these is a truth of which I have long been convinced; to wit, that when a seeming discordance arises between the portrayals of a canal, it is commonly not a case of mistake nor of change, but one of separate identity. The canal has not shifted its place, nor has an error been committed; the fact is that one canal has been observed at one time, another at another.

So it was here, and thus were the old and the new observations reconciled. There had been no mistake in either. Two separate canals accounted for the discrepancy, and only an unfounded distrust of the accuracy possible in such observations was to blame for any failure to recognize the fact.

Now, scrutiny of the notes upon the appearance of the two canals, together with their labeling by the seasonal

longitudes of the planet at the dates they were made, discloses a curious relation between the two. The seasonal longitudes are important, as they date the phenomena according to the Martian calendar. Ordered thus, the successive aspects reveal first a seasonal change in each canal and then over and above this a



CARTOUCHES
OR
CURVES OF VISIBILITY
OF
AMENTHES, THOTH and THEIR COMBINATION.

secular one. And this secular change was such as to cause the two canals to alternate in visibility. When the one was present the other was not, and *vice versa*.

We shall see this more clearly and at the same time bring out a curious relation between the two systems, the broken bow of the Thoth-Nepenthes-Triton and the straight arrow of the Amenthes, while looking at the

cartouches of the Thoth, the Amenthes, and a combination of both given in the plate on previous page.

The antithetical character of the two canals is apparent. But what is further interesting, the combination cartouche of both bears a singular resemblance to that of the mean canal of the north tropic zone, the zone to which both canals belong. Here, then, is a combination which is perfectly regular while each of its constituents is anomalous.

And now we come to something as important: at the opposition of 1905 the curious alternation metamorphosis was enacted anew. The Amenthes appeared, disappeared to be replaced by the Thoth, and then reappeared again beside the other. This corroboration of behavior showed the previous observations to have been due to no mistake, and only served to deepen the interest in this last and more singular phase of canal conduct.

CHAPTER XXVI

ARCTIC CANALS AND POLAR RIFTS

LAST in time but not least in importance of the details of canal development to be detected is one that connects these strange features directly with the melting of the polar caps. The cartouches showed that such connection was to be inferred; the facts now to be recorded depict it by an identity of place between certain phenomena of the two subjects following one another in order of time.

On January 8, 1897, while scanning the planet, I was suddenly ware of a rift in the north polar cap. It ran a little to the west of south from where it started in at the cap's edge and went clean through to the limb, the pole being then slightly tilted away from us. At the time it seemed to be the first rift ever seen in that cap; but on opening a little later Schiaparelli's *Memoria Quarta*, which had just arrived, the first thing my eye fell on was a drawing of a rift in the north polar cap observed by him when the planet had held the like attitude toward the Earth thirteen years before. Reference to its longitude showed it to be the identical

rift, seen again after all these years and the only one so far seen in the northern cap.

At the next opposition more rifts were detected, one in especial on December 27, running from Arethusa Lucus, then upon the edge of the cap, athwart the snow in a northwesterly direction.

In the forepart of the opposition of 1901, which in its Martian season corresponded to that in 1897, when the rift had been observed, many rifts were detected in the cap, and among them one traversing the cap north-northeasterly in longitude 136°.

So far the season when the cap had been observed was that when the rifts were in process of forming. The ground they and the snow-cap covered had not yet at any opposition been uncovered.

It was only when my observations began in the latter half of the opposition of 1901 that, the season on Mars having so far advanced, all snow in those latitudes had melted. Then appeared, however, the canal Hippalus, an arctic canal of some importance, lying on that part of the planet previously occupied by the polar cap. When later studying the observations on the rifts I remembered this canal, and turning to the drawing made some months before to compare the two critically, discovered that the canal occupied the precise position held earlier by the rift. One had said the rift had never vanished, but that the white

surrounding it had simply turned to ochre. Here, then, was a striking coincidence of place, too exact to be the result of chance.

Impressed by the identity, I examined all the other rifts seen early in 1901, comparing them with the arctic canals seen later, to the finding of no less than five cases of the same coinciding positions.

The importance of the identification here made of an arctic canal with a previous rift in the polar cap has led me to make a list of the canals thus identified at this opposition.

	Visible as a Rift	Visible as a Canal
Hypanis	January 1 and February 4	April 18 (?), May 20, 22, 27, June 4, 5, 6, 7, 8, 25
Hippalus	January 19 and February 4	April 18, May 27
Rhombites	February 4	May 27
Python	February 20	March 31
Zygatis	January 18, 19	May 7, June 3 to 8

If it be asked why these canals do not appear recorded at the March presentation as either the one phenomenon or the other, the answer is twofold. First, because they showed as shadings lost amidst a shaded mass; and, secondly, the observations at several oppositions indicate a great amount of haze over the region at that season of the Martian year.

We may now go back to the very first rift, that of 1897. The Martian season grew later with each suc-

ceeding opposition, and it so chanced, abetted by this fact, that the delaying snow was never seen covering that part of the planet again and so, of course, not the rift. The Martian summer in those high latitudes came on, and with it brought the great arctic canal, the Jaxartes, into conspicuousness. The canal in consequence had been observed for some time before it proclaimed itself the apotheosis of a rift and that of the first and most important rift of all. Comparison of position, however, entirely confirmed the conjecture and added another and the most striking of all to the list.

These six canals, on the whole the largest which run into the northern cap, have thus a dual character. Starting originally as rifts, they later come out unmistakably as canals. So that we may say in general that the two phenomena are different seasonal states of the same thing. This instantly explains the rifts, the origin of which we found of so difficult, not to say impossible, interpretation before in these pages, and incidentally it confirms what we deduced on other grounds as the character of the canals; to wit, strips of vegetation. For if the cap covered desert and fertility alike, it is precisely over the latter that it would first melt.

Vegetation has the property of melting snow. The metabolism of the plant, like that of the animal, though

in a less degree, generates caloric. A living animal is warm, even the so-called cold-blooded ones, in some sort, and a growing plant is too. The chemic processes concerned give off heat, though in such small quantities that we are often not aware of it. While the plant lies dormant it stays cold, but the moment its sap begins to run under the rays of the spring sun it rises in temperature above its winter surroundings. All it needs to this awakening is sun and water, and both it gets in its place in the polar cap after the passing of the vernal equinox. The time, therefore, is suitable, for it is not till after that equinox is passed that any of the above phenomena occur. In consequence the snow about it melts and the plants themselves show as dark rifts splitting the cap.

This quite unexpected identity of two seemingly diverse phenomena, and the unsolicited support its only explanation lends to the general theory, is an instance of what is constantly occurring as observation of the planet is pushed farther and farther. Facts every little while arise which prove to fit into place in the scheme when neither the facts nor their fitness could have been foreseen.

CHAPTER XXVII

OASES; KINEMATIC

SUBJECT to change also are the oases; and in the same manner apparently as the canals. They grow less evident at a like season of the Martian year. They do this seemingly by decreasing in size. Whereas in the full expanse of their maturity they show as round spots of appreciable diameter, as the season wanes they contract to the smallest discernible of dots. All but the kernel, as it were, fades out, and even this may disappear from sight. The Phœnix Lake in its summer time is a very dark circular spot, small indeed yet of definite extension; in its winter it shrinks to a pin point, and is often not visible at all. Sometimes the husk apparently persists, a ghostlike reminiscence of what it was, with the kernel showing dark-pointed in its centre. Thus the Lucus Lunae appeared at the opposition of 1905. A faint wash betokened the presence of the Lucus, through which now and again a black pin-point pierced.

In this visible decrease of size we get a revelation as to what takes place impossible in the case of the canals,

the tenuous character of which precludes more than inference as to the process.

Like the canals, latitude, together with the suitable season of the planet's year, are the determining factors in their development. In what corresponded to our July of the northern hemisphere the oases in the sub-arctic and north temperate zones were conspicuous; black spots that showed in profusion along the parallels of 40°, 50°, and 60° north. At the same time the equatorial ones, those along the Eumenides-Orcus, which had been most evident in 1894, hardly came out. It had been their time then as it was that of the others now. The law of development is not so simple as on the earth, depending, like that of the canals, not only upon the return of the sun, but upon the advent of the water let loose from about the polar caps. Thus the equatorial oases are subject to two seasonal quickenings, one from the north, the other from the south.

In regard to their method of evolution or devolution a most curious observation happened to me in 1903. Usually the oases are of solid tone throughout; equally sombre from centre to circumference. But in this case such uniform complexion found exception. On March 1, 1903, the Ascraeus Lucus came out strangely differentiated, a dark rim inclosing a less dark kernel. The sight was odd enough to command comment in the

shape of a sketch which accompanied the note, and the further remark that other spots had similarly that year affected the like look. That the effect was optical did not seem to me the case. Other spots at other times showed nothing of the sort. If it was due to objective cause it gathers circumstance from what was then the Martian time of year. For the season was such that the spot should then have been in process of waning; and the effect would indicate that in so doing the tone of the centre went first, that of the circumference fading last. This would be in accordance with a growth proceeding outward and a decay that followed in its steps.

When to this we add the look of the oases at the antithetic season, — often a faint shading only, with or without a darker pin-point at its core, — we are led to the belief that the area of the oasis is unchangeable and that its growth means a deepening of tint.

So far, then, as it is possible to particularize them, the oases develop from a small nucleus, perhaps twenty miles in diameter, perhaps less, and from this spread radially till they attain a width of seventy-five or one hundred miles. If the oasis be associated with a double canal, this maximum width exactly fits the space between the twin lines. Even when no double enters the oasis, the size is about the same. This size attained, they hold it for some months. Then they proceed to

fade out to their initial nucleus, and after a sufficient rest the process starts over again.

With the carets something of the same sort seems to take place — if we may consider as betokening a general law the fact that in 1894 the carets at the mouths of the Phison and Euphrates developed before their affiliated canals. But about them much less is yet known, and we must be content to say that the observations of 1905 made at the opposite season of the canal's year seem to bear this out.

PART IV

EXPLANATION

CHAPTER XXVIII

CONSTITUTION OF THE CANALS AND OASES

AS rational science does not rest content with raw results, it now becomes obligatory, by marshaling the facts to suitable discussion, to seek to find out what they mean. Now, so soon as we scan these phenomena for some self-interpretation, we perceive one characteristic of the lines which at once appears to direct us to their nature and justifies itself as a signpost with increasing certainty as we read on. This trait is the very simple yet most significant one of showing intrinsic change: the lines alter in visibility with time. This primary proclivity we do not even need the cartouches to establish. That the lines change is palpable to any one who will watch them long enough. Schiaparelli was struck by the fact early in his study of the planet, and it forces itself on the notice of any careful observer who compares his own observations with one another at intervals. But though the cartouches are not needed to a first revelation of mutability, they serve to certify and precise it to much further information on the subject. For, that these changes are not extrinsic, that is, are not caused by varying definition, distance,

or illumination, they make patent even to those who have never seen the things themselves by disclosing respective differences of behavior in lines similarly circumstanced optically. The change is therefore intrinsic, and the question arises to what can such intrinsic change be due.

In searching for cause, attention is at once attracted by another series of transmutations that manifests itself upon the disk, in the orderly melting of the polar caps. For the existence of the two sets of metamorphoses suggests the possibility of a connection between them. The inference is strengthened when we note that not only are both periodic, but that furthermore the period of the two is the same. Each polar cap runs through its gamut of change in a Martian year; the canals also complete their cycle of growth and decay in a Martian twelvemonth. The only difference between the two is that each polar cap has but one maximum and one minimum in the course of this time, while most of the canals have two of each, though the maxima are not alike nor the minima either.

Not only is the period of the two series of changes the same, but the one follows the other. For the development of the canals does not begin till the melting of the polar cap is well under way. Now, as the polar cap disintegrates it gives rise, as we have seen, to a dark belt of blue-green which fringes its outer edge and retreats

with it as it shrinks. This tells, directly or indirectly, of a product let loose. After this belt has been formed the canals nearest to it proceed to darken, then those a little farther off follow suit, and so the wave of visibility rolls in regular routine down the disk. Here, then, at the outset we have a chronic connection between the two phenomena, the disintegration of the cap and the integration of the canals.

Of water we saw that the caps were undoubtedly composed, and to water, then, let loose by the melting of the cap, we may inferably ascribe the thaumaturgy in the development of the canals. But it is not necessary to suppose that this is done directly. That the increased visibility of the canals can be due to a bodily transference of water seems doubtful, if for no other reason than the delay in the action. Considerable time intervenes between the disappearance of the cap and the appearance of the canals, except in the case of such as have been covered by it. Transformation consequent upon transference, however, would account for hesitancy. A quickening to vegetal growth would produce the counterpart of what we see. If, set free from the winter locking up, the water accumulated in the cap then percolated equatorward, starting vegetation in its course, this would cause the increased visibility of the canals and at the same time explain the seeming delay, by allowing for the

time necessary for this vegetation to sprout. This is certainly the most satisfactory explanation of the phenomena.

Thus started, the vegetal quickening would pass down the planet's surface and give rise to what we mark as seasonal change. But, though in one sense of seasonal character, a little consideration will show that it would be quite unlike the seasonal change which we know on earth.

Could we see our earth from some standpoint in space, we should mark, with the advent of spring, a wave of verdure sweep over its face. If freedom from cloud permitted of an unimpeded view, this flush of waking from winter's sleep would be quite evident and could be seen to spread. Starting from the equator so soon as the sun turned north, it, too, would travel northward, and, distancing the sun, arrive by midsummer well into the arctic zone. Here, then, we should note, much as we note it on Mars, a tint of blue-green superpose itself successively upon the ochre ground; but the mundane and the Martian vegetal awakening would differ in one fundamental respect; the earthly wave would be seen to travel from equator to pole, while the Arian travels from pole to equator. Though clearly seasonal in character, both of them, the transformations would be opposite in action. Some other cause, then, must be at work from what we are familiar

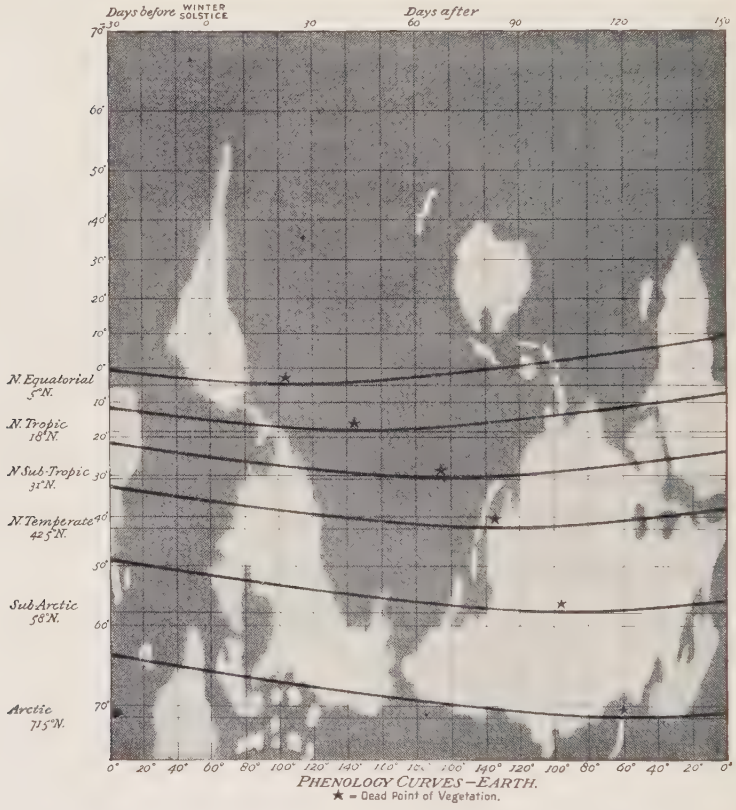
with on earth. This other cause is the presence or absence of moisture.

Two factors are necessary to the begetting of vegetal life, the raw material and the reacting agent. Oxygen, nitrogen, water, and a few salts make up the first desideratum, the sun supplies the second. Unless both be present, the quickening to life never comes. Now, the one may be there and the other not, or the other there and the one not. On earth the material including water is, except in certain destitute localities, always present; the sun it is that periodically withdraws. Observant upon the return of the sun is therefore the annual recurrence of vegetal growth.

On Mars, on the contrary, water is lacking. This we now know conclusively from other phenomena the disk presents which have no connection with the present investigation and are, therefore, unprejudiced witnesses to the fact. No permanent bodies of water stud its surface. That the so-called seas are traversed by dark lines permanent in place is one of several proofs of this. The only surface water the planet knows comes from the melting of its polar caps. Vegetation cannot start until this water reaches it. Consequently, though the sun be ready, vegetation must wait upon the coming of the water, and starting from near the pole follow the frugal flood equatorward.

Now, such contrariety of progression to what we

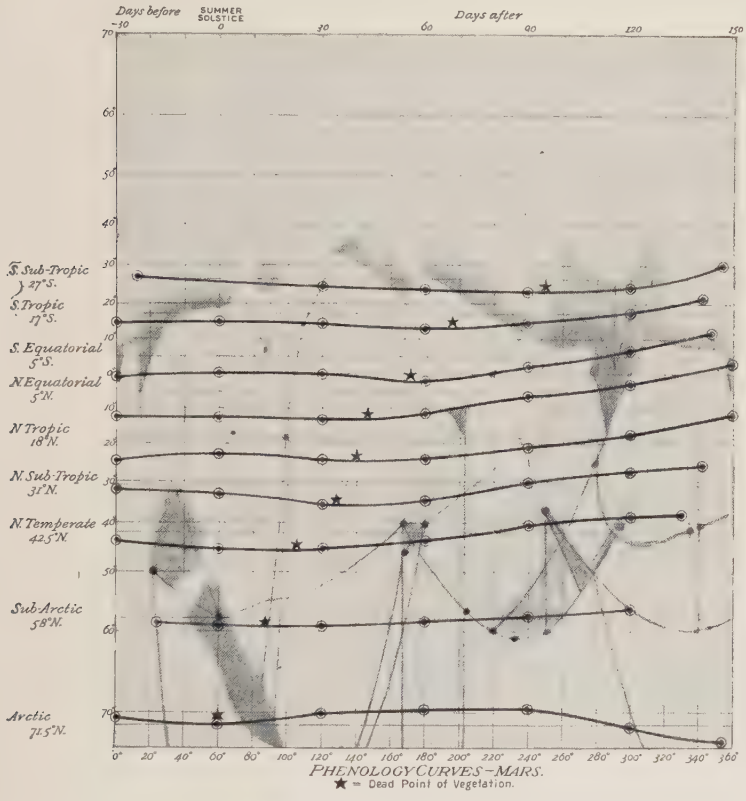
should observe in the case of the earth could we view it from afar is exactly what the curves of visibility of



(From paper in *Proc. Amer. Phil. Soc.*, by Percival Lowell.)

the canals exhibit. Timed primarily, not to the return of the sun but to the advent of the water, vegetal quickening there follows, not the former up the latitudes but the latter down the disk. For better under-

standing, the two curves of phenological quickening, the mundane and the Martian, are shown in the dia-



(From paper in *Proc. Amer. Phil. Soc.*, by Percival Lowell.)

grams. The plates represent the surfaces of the two planets, that of the earth being shown upside down with south at the top so as to agree with the telescopic depiction of the topography of Mars. The stars mark the

epoch of the dead-point of vegetation at successive latitudes; the time increasing toward the right. The curves, it will be noticed, are bowed in opposite ways. The bowed effect is due in part to Mercator's projection; in part it may represent a real decrease in speed with time. But what is strikingly noticeable is the opposite character of the advance to the right, the one curve running up the disk, the other down it. This shows that the development of vegetation proceeded in opposite directions over the surface.

Thus is the opposed action upon the two planets accounted for, and we are led to the conclusion that the canals are strips of vegetation fed by water from the polar caps, and that the floral seasons there as affecting the canals are conditioned, not as they would be with us, directly upon the return of the sun, but indirectly so through its direct effect upon the polar snows.

Once adventured on the idea of vegetation, we find that it explains much more than the time taken by the wave of canal-development down the disk. It accounts at once for the behavior of the canals in the three northern zones: the polar, arctic, and sub-arctic. The mean cartouches of these three zones dip down at their latter end instead of rising there, as is the case with the cartouches of the mean canals farther south. This dip denotes that the most northern canals were waning already by the middle of their August, though

the others showed no such tendency; while the date of the deposition of the frost in these northern latitudes shows that they were started upon their course toward extinction before the snow itself had covered them. In other words, they were not obliterated but snuffed out. That their decline was thus preparatory to the coming of the first snowfall or frost-fall, sufficiently severe to whiten the ground so that it did not melt the next day, is suggestive of their constitution. It is clear that they were not abruptly cut off by the frost, but were timed by nature to such extinction. Vegetation would behave in just this way, since evolution would accommodate the career of a plant to its environment.

The first question to present itself chronologically in the canals' annual history is connected with the size of the cap. Unfortunately for the simplicity of the phenomena, the cap is not an extensionless source of flow, but an extended surface melting from the outer edge in. It would seem, therefore, that water liberated from the outer parts should have an effect before the main body of it were ready to begin its general march down the disk. There should be, one would think, at least a partial action, locally, before the main action got under way. Now, there are certain canals that show cartouches increasing apparently from the time observations began, and the most pronounced is the Jaxartes, which lies of all the canals observed the farthest

north. Now, the cartouches were founded on canals quickened from the north polar cap. The farther north the canal, therefore, the greater the likelihood of its showing the phenomena.

That we note such canals is therefore not only not subversive, but actually corroboratory, of the law it seems at first to shake. That all the canals of these zones do not show a like cartouche-profile is not necessary, a part of them being dependent, not upon the earlier, but upon the later liberated flow, and thus partaking in the general law, which grows uniform lower down the latitudes.

As the action from one polar cap proceeds, not only down to the equator, but across it into the planet's other hemisphere, it appears that much, at least, of the surface of Mars has two seasons of vegetal growth, the one quickened of the north polar cap, the other of the southern. How far the polar spheres of action overlap it is not possible at present to affirm, as the canals at this opposition were only visible to 35° south latitude. That the north polar quickening goes down so far is vouched for, and it is probable from other observed phenomena that it goes farther.

The alternate semi-annual quickening also discloses itself directly in the cartouches; the previous semestral growth from the south polar cap actually showing in them before the impulse from the north began. The

slow falling of their curves to the minimum preceding their later rise is nothing less than the dying out of the effect started six months before from the south. The gentler gradient of their fall proclaims a gradual lapse, just as the subsequent sharper rise points to the advent of a fresh impulse. And this deduction seems to be borne out by another circumstance. There is some evidence of decrease in the pre-minimal gradient southward. This is telling testimony to the source whence the impulse came. For if it originated at the south and traveled northward, the southern canals would be the first to be affected and the first to die out, and thus show a longer dead season, exhibited in the cartouches as a more level stretch.

Lastly, the explanation of the canals as threads of vegetation fays in with the one which has been found to meet the requirements of the blue-green areas; while the fact that they prove to develop as they do, reversely to what would take place on earth, is exactly what all we have latterly learnt about the surface conditions of the planet would lead us to expect.

From what has just been said we see that the latest observations at Flagstaff confirm the earlier ones, and, what is especially corroborative, they do so along another line. The former were chiefly static, the latter kinematic. In other words, the behavior of the canals in action bears out the testimony of their appearance at rest.

CHAPTER XXIX

LIFE

STUDY of the fundamental features of Martian topography has disclosed, as we have seen, the existence of vegetation on the planet as the only rational explanation of the dark markings there, considered not simply on the score of their appearance momentarily, but judged by the changes that appearance undergoes at successive seasons of the Martian year. Thus we are assured that plant life exists on the planet. We are made aware of the fact in more ways than one, but most unanswerably for that trait to which vegetation owes its very name, — its periodic quickening to life. Thus the characteristic which has seemed here most distinctive of this phase of the organic, so that man even christened it in accordance, has proved equally telltale there.

Important as a conclusion this is no less pregnant as a premise. For the assurance that plant life exists on Mars leads to a further step in extramundane acquaintance of far-reaching import. It introduces us at once to the probability of life there of a higher and more immediately appealing kind, not with the vagueness of

general analogy, but with the definiteness of specific deduction. For the presence of a flora is itself ground for suspecting a fauna.

Of a bond connecting the two we get our first hint the moment we look inquiringly into the world about us, that of our own earth. Common experience witnesses to a coexistence which grows curious and compelling as we consider it. For it is not confined to life of any special order, but extends through the whole range of organisms of both kinds from the lowest to the highest. Algæ and monera, orchid and mammal, occur side by side and with a certain considerate poverty or richness, as the case may be. Luxuriance in the one is matched by abundance in the other; while a scanty flora means a poor fauna. This of which we have been aware in regions round about us from childhood grows in universality as we explore. Wherever man penetrates out of his proper sphere he finds the same dual possession of the land or the sea, and a similar curtailing or expanding of both tenantries together. No mountain top so cold but that if it grow plants, it supports insects and animals, too, after its kind; no desert so arid but that creeping things find it as possible a habitat as life that does not stir. Even in almost boiling geysers animalcula and confervæ share and share alike. Only where extreme conditions preclude the one do they equally debar the other.

Proceeding now from the fact to its factors we perceive reasons for this tenure in common of the land by the vegetal and animal kingdoms. Examination proves the two great divisions of the organic to be inextricably connected. It strikes our notice first in the relation of plants to animals. It is of everyday notoriety that animals eat plants, though it is less universally understood that in the ultimate they exist on nothing else. Plants furnish the food of animals; not as a matter of partial preference but of fundamental necessity. For the plant is the indispensable intermediary in the process of metabolism. Without plants animals would soon cease to exist, since they are unable to manufacture their own plasm out of the raw material offered by inorganic nature. They must make it out of the already prepared plasm of plants or out of other animals who have made it from plants. So that in the end it all comes back to plant production. The plant is able to build its plasm out of chemical substances; the animal cannot, except in the case of the nitro-bacteria, begin thus at the lowest rung of the alimentary ladder.

But the converse of this dependence is also largely true. Plants are beholden to animals for processes that in return make their own life possible. The latter minister to the former with unconscious service all the time, and with no more arrogant independence than do our domestics generally nowadays. The inconspicuous

earthworm is the fieldhand of nature's crops, who gets his own living by making theirs. Without this day and night laborer the soil for want of stirring had remained less capable of grass. Above ground it is the same story. Deprived of the ministrations of insects many kinds of plants would incontinently perish. By the solicited visits of bees and other hymenoptera — what generically may be classed by the layman as flutter-bys — is the plant's propagation made possible. Peculiarly well named, indeed, are the hymenoptera, seeing that they are the great matrimonial go-betweens, carrying pollen from one individual to another and thus uniting what otherwise could not meet. Spectacular as this widespread commerce is, it forms but portion of the daily drama in which animals and plants alike take part. From forthright bargainings of honey for help, we pass to less direct but no less effective alliance where plants are beholden to animals for life by the killing of their enemies or the weeding-out of their competitors, and from this to generic furtherance where the interdependence becomes broadcast. In the matter of metabolism the advantage is not all upon one side. In the katabolic process of that which each discards are the two classes of life mutually complimentary, — the waste of the one being the want of the other, — carbonic acid gas being given off by the animal, oxygen by the plant. In biologic economy it is daily more

demonstrable that both are necessary constituents to an advancing whole, and that each pays for what it gets by what it gives in return.

That they are thus ancillary as well as coexistent today leads us to confront for them a community of origin in the past; and further study confirms the inference. Both paleontology and entomology, or the science of the aged and the science of the young, prove such ancestry to be a fact. By going back from the present into the past, or, what amounts to substantially the same thing, by descending in the scale of life to the lowest known forms of organism, we find proof of concomitance, cogent because congenital. At the time when inorganic chemical compounds first passed by evolution into organic ones, the change was of so general a character that even such tardy representatives of it as survive today tax erudition to tell to which of the two great kingdoms they belong, the vegetal or the animal. Simplest and most primitive of known organisms are the chromacea, unnucleated single cells as Haeckel has shown, and next to them in order come many of the bacteria, also of simple unnucleated plasm. So little do the majority of the bacteria differ morphologically from the chromacea, that on the score of structure the two are not to be catalogued apart. Both are as elemental as anything well can be, which only their diet serves to divide. Each is an organism with-

out organs, thus belying the dictionary definition of both animals and plants. Etymologically they are not organic yet manifestly are alive, and only in their action are unlike. The chromacea are plasm-forming beings, and therefore they are plants; the bacteria are plasm-eating beings, and so are animals. Even this distinction is not always preserved. As Haeckel tells us: "the nitro-bacteria which dwell in the earth having the vegetal property of converting ammonia by oxidation into nitrous acid and this into nitric acid, using as their source of carbon the carbonic acid gas of the atmosphere. They feed, like the chromacea, on simple inorganic compounds." Here, then, we have, close to the threshold of organic life, unorganized organisms, roughly speaking coeval and differing in a sense but little, either of them, from inorganic crystals; and yet the one is an animal, the other a plant. Progenitors of the two great divisions of life, they were themselves concomitantly evolved, either side by side or as offshoots both of a common stock. Now, if the ancestors of the two great organic kingdoms were thus simultaneously produced here, we are warranted in believing that they would similarly be produced elsewhere, given conditions suitably alike. In consequence, if we detect the presence of the one, we already have an argument for inferring the other. Not to complete our syllogism would be to flaunt a lack of logic in nature's face.

Rationally viewed, then, the general problem of life in other worlds reduces itself to a question of conditions. Since certain physical results follow inevitably upon certain physical premises, if we can assure ourselves of the proper premises we may look to nature for their conclusion. *A priori*, then, the possibility of life becomes one of habitat. If the environment be suitable life will ensue. What makes for such a mediary *milieu* is, like most cosmic processes, in its fundamentals of interesting simplicity; for the production of a proper nidus depends primarily upon the mere size of the body parentally concerned. If a planet be big enough it will inevitably bring forth life, because of conditions suitable to its generating; if too small it will remain sterile to the end of time.

That size should be the determining factor whether a planet shall be fecund or barren may seem at first thought strange. Yet that it is so admits of no rational doubt. All that we see of bodies about us shows its truth, and what we have learnt of cosmic process enables us in some sort to discern why. In order for evolution, such as we mark it upon the earth, to be possible, the parent body must have been at one time at a high temperature, since only under great heat can the primal processes occur. But for this generation of caloric the aggregate mass of the particles, the falling together of which makes the planet, and their stoppage its inter-

nal heat, must be large. The sun's rays alone are insufficient to cause the necessary temperature; the heat must come from within, though it be helped from without. Even here the action is abetted by a large body. For a planet to entrap the sun's rays or even to preserve its own internal warmth, an atmosphere is needed, and it takes a large body to retain an atmospheric covering sufficiently long. Yet without it not only would there be no suitable state, but no medium in which organic or even inorganic reactions could go on. Lastly, water, the essential nidus for the organism's early stages, has its presence similarly conditioned. For this, like the atmosphere, would from a small body speedily vanish away. Thus the planet itself is the life-producing body, although the sun furthers the process when once begun.

That the needed substances are planetarily present, what we know of the distribution of matter astronomically sufficiently attests. What we find in meteorites shows that the catastrophe which preceded our present solar system's birth scattered its elemental constituents throughout its domain, and thus when they came to be gathered up again into planets that these must have been materially the same. The manner, not the matter, then, is alone that about which we are concerned.

Now, if the mass of matter gravitating together to form a planet be sufficient to produce the proper inor-

ganic conditions, the organic must follow as a matter of course. That the organic springs from the inorganic is not only shown by what has taken place on earth, but is the necessary logical deduction from its decay back into the inorganic again. As Nägeli admirably observes: "The origin of the organic from the inorganic is, in the first place, not a question of experience and experiment, but a fact deduced from the law of the constancy of matter and force. If all things in the material world are causally related, if all phenomena proceed on natural principles, organisms which are formed of and decay into the same matter must have been derived originally from inorganic compounds."

The original oneness of the two, the fact that the organic sprang from the inorganic, is shown by the cousinly closeness of the lowest organic with the highest inorganic substances. The monera are suggestive of crystals in their uniformity of structure. Both are homogeneous or approximately so. Again, both grow by taking from what they come in contact with that which they find suitable and so add to their body by homogeneous accretion. Finally, when grown too large for single life, they part into similar crystals or split into identical cells. The difference between the division of the crystal and the fission of the cell is small in kind; much less than that later differentiation in genesis into parthenogenesis and sexual reproduc-

tion. Yet here we unhesitatingly trace an assured relationship. It were straining at a gnat to swallow a camel to doubt it in the other.

Just as the two behave analogically alike in their own action, so do they observe a like attitude toward nature. They thus point to their common origin. The monera are resemblant of chemical compounds in their superiority to external influences. To outward conditions of temperature and humidity the chromacea are much as sticks and stones. Some species may remain for long frozen in ice, Haeckel observes, and yet wake to activity so soon as it thaws. Others may be completely desiccated, and then resume their life when put in water after a lapse of several years. Thus both in their deathlike lives and in their living immortality the chromacea are close to inorganic things.

From preference, however, these lowest forms of life affect what to us would be unbearable temperatures. Many of the chromacea live in hot springs at temperatures of 123° to 176° Fahrenheit, in which no other, that is, no higher, organism can dwell. This choice of habitat is in line with the other details of their evolutionary career. For it, too, is in keeping with the conditions of crystalline growth, halfway as it were on the road to them; the forming of crystals beginning at a temperature higher still. And we perceive from it that the passing of the inorganic into the organic is

brought about by a lowering of the temperature of the parent planet. This again, is in line with the evolution of chemical complexity. Let the heat become less, and higher and higher chemical compounds, finally the organic ones, become possible. That evolution is nothing else than such a gradually increasing chemical synthesis is forced on one by study of the facts. Once started, life, as paleontology shows, develops along both the floral and the faunal lines side by side, taking on complexity with time. It begins so soon as secular cooling has condensed water vapor to its liquid state; chromacea and confervæ coming into being high up toward the boiling-point. Then, with lowering temperature come the seaweeds and the rhizopods, then the land plants and the lunged vertebrates. Hand in hand the fauna and flora climb to more intricate perfecting, life rising as temperature lowers.

We perceive then that, considered *a priori*, the possibility of life on a planet is merely a question of the planet's size; and then pursuantly that the character of that life is a matter of the planet's age. But age again is a question of size. For the smaller its mass the quicker the body cools, and with a planet, growing cold means growing old. Within the bounds that make life possible, the smaller the body the quicker it ages and the more advanced its denizens must be. Just how far the advance goes we may not assert dogmatically in

a given case, since not relative age alone but absolute time as well is concerned in it. It may be that nature's processes cannot be hurried, and that for want of time development may in part be missed. But from general considerations the limit of the time needed seems well within most planetary careers.

Now, the aspect of the surface of Mars shows that both these conditions have been fulfilled. Mars is large enough to have begotten vegetation and small enough to be already old. All that we know of the physical state of the planet points to the possibility of both vegetal and animal life existing there, and furthermore, that this life should be of a relatively high order is possible. Nothing contradicts this, and the observations of the last ten years have rendered the conclusion then advanced only the more conclusive. Even the evidence of the past state of the planet confirms that given by its present one. That with us life came out of the seas finds its possible parallel in the fact that seas seem once to have existed there, leaving their mark discernible to-day. Life, then, had there as here the wherewith to begin. That we find air and water in both shows that it had the means to continue once begun. That it then ran a like course is further witnessed by what we now detect. The necessary premises, then, are there. More than this. One half of the conclusion, vegetal life, gives evidence of itself.

CHAPTER XXX

EVIDENCE

OF the existence of animal life upon a far planet any evidence must, of necessity, assume a different guise from what its flora would present. Plant life should be, as on Mars we perceive it is, recognizable as part and parcel of the main features of the planet's face. In no such forthright manner could we expect an animal revelation. The sort of testimony which would render the one patent would leave the other obstinately hid.

So long as animate life was in the lowest sense animal, it would not be seen at all, though it were as widespread as the vegetal life all about it. Reason for this lies in their receptive character. Plants are fixtures; where they start they stay; while from the nature of their food, derived directly from the soil and from the air, and conditioned chiefly by warmth and moisture, like forms inhabit large areas and by their massed effect make far impression. With animals it is otherwise. They feed by forage, from beetle to buffalo, roaming the land for sustenance. Thus, both for paucity of number and from not abiding in one stay they must escape notice

at a distance such that as individuals they fail to show; to say nothing of the fact that the flora usually overtop the fauna, and so help to hide the latter while appearing itself distinct. Any far view of our earth gives instance of this. Seen from some panoramic height, forest and moorland lie patently outspread to view, yet imagination is taxed to believe them tenanted at all. Unless man have marred the landscape not a sign appears of any living thing. One must be near indeed to note even such unusual sights as a herd of buffalo in the plains or those immense flights of pigeons, that in former years occurred like clouds darkening the air. From the standpoint of another planet, through any such direct showing animal existence would still remain unknown.

Not until the creatures had reached a certain phase in evolution would their presence become perceptible; and not then directly, but by the results such presence brought to pass. Occupancy would be first evidenced by its imprint on the land; discernible thus initially not so much by the bodily as by the mind's eye. For not till the animal had learnt to dominate nature and fashion it to his needs and ends would his existence betray itself. By the transformation he wrought in the landscape would he be known. It is thus we should make our own far acquaintance; and by the disarrangement of nature first have inkling of man.

That it is thus we should betray ourselves, a consideration of man's history will show. While he still remained of savage simplicity, a mere child of nature, he might come and go unmarked by an outsider, but so soon as he started in to possess the earth his handicraft would reveal him. From the moment he bethought him to till the ground, he entered upon a course of world-subjugation of which we cannot foresee the end; but he has already advanced far enough to give us an idea of the process. It began with agriculture. Deforestation with its subsequent quartering of crops signalized his acquisition of real estate. His impress at first was sporadic and irregular, and in so far followed that of nature itself; but as it advanced it took on a methodism of plan. Husbandry begot thrift, and augmented wants demanded an increasing return for toil; and to this desirable end systematization became a necessity. At the same time gregariousness grew and still further emphasized the need for economy of space and time. In part unconsciously, man learnt the laws that govern the expenditure of force and more and more consciously applied them. Geometry, unloosed of Euclid, became a part of everyday life as insidiously as M. Jourdain found that he had been talking prose. Regularity rules to-day, to the lament of art. The railroad is straighter than the turnpike, as that is straighter than the trail. Communication is now too

urgent in its demands to know anything but law and take other than the shortest path to its destination. Tillage has undergone a like rectification. To one used to the patchwork quilting of the crops in older lands the methodical rectangles of the farms of the Great West are painfully exact. Yet it is more than probable that these material manifestations would be the first signs of intelligence to one considering the earth from far. Our towns would in all likelihood constitute the next; and, lastly, the great arteries of travel that minister to their wants. Their scale, too, would render them the first objects to be observed. Farming as now practiced in Kansas or Dakota gives it a certain cosmical concern; fields for miles turning in hue with the rhythm of the drilled should impress an eye, if armed with our appliances, many millions of miles away.

Even now we should know ourselves cosmically by our geometrical designs. To interplanetary understanding it is this quality that would speak. Still more so will it tell as time goes on. As yet we are but at the beginning of our subjugation of the globe. We have hardly explored it all, still less occupied it. When we do so, and space shall have become enhancedly precious, directness of purpose with economy of result will have partitioned so regularly the surface of the earth as to impart to it an artificiality of appearance, and it becomes one vast coördinated expanse subservient entirely to

the wants of its possessors. Centres of population and lines of communication, with tillage carried on in the most economic way; to this it must come in the end.

Nor is this outcome in any sense a circumstance accidental to the earth; it is an inevitable phase in the evolution of organisms. As the organism develops brain it is able to circumvent the adversities of condition; and by overcoming more pronounced inhospitality of environment not only to survive but spread. Evidence of this thought will be stamped more and more visibly upon the face of its habitat. On earth, for all our pride of intellect, we have not yet progressed very far from the lowly animal state that leaves no records of itself. It is only in the last two centuries that our self-registration upon our surroundings has been marked. With another planet the like course must in all probability be pursued, and the older the life relatively to its habitat the more its signs of occupation should show. Intelligence on other worlds could then only make its presence known by such material revelation, and the sign-manuals of itself would appear more artificial in look as that life was high in rank. Given the certainty of plant-life, such markings are what one would look to find. Criticism which refuses to credit detail of the sort because too bizarre to be true writes itself down as unacquainted with the character of the

problem. For it is precisely such detail which should show if any evidence at all were forthcoming.

If, now, we turn our inquiry to Mars, we shall be fairly startled at what its disk discloses. For we find ourselves confronted in the canals and oases by precisely the appearances *a priori* reasoning proves should show were the planet inhabited. Our abstract prognostications have taken concrete form. Here in these rectilineal lines and roundish spots we have spread out our centres of effort and our lines of communication. For the oases are clearly ganglia to which the canals play the part of nerves. The strange geometricism which proves inexplicable on any other hypothesis now shows itself of the essence of the solution. The appearance of artificiality cast up at the phenomena in disproof vindicates itself as the vital point in the whole matter. Like the cachet of an architect, it is the thing about the building that established the authorship.

Though the Earth and Mars agree in being planets, they differ constitutionally in several important respects. Even to us the curious network that enshrouds the Martian disk suggests handicraft; it implies it much more when considered from a Martian standpoint.

CHAPTER XXXI

THE HUSBANDING OF WATER

THAT the canals and oases are of artificial origin is thus suggested by their very look; when we come to go further and inquire into what may be their office in the planet's economy, we find that the idea in addition to its general probability now acquires particular support. For this we are indebted in part to study of their static aspect, but chiefly to what has been learnt of their kinematic action.

Dearth of water is the key to their character. Water is very scarce on the planet. We know this by the absence of any bodies of it of any size upon the surface. So far as we can see the only available water is what comes from the semi-annual melting at one or the other cap of the snow accumulated there during the previous winter. Beyond this there is none except for what may be present in the air. Now, water is absolutely essential to all forms of life; no organisms can exist without it.

But as a planet ages, it loses its oceans as has before been explained, and gradually its whole water supply. Life upon its surface is confronted by a growing scarcity

of this essential to existence. For its fauna to survive it must utilize all it can get. To this end it would be obliged to put forth its chief endeavors, and the outcome of such work would result in a deformation of the disk indicative of its presence. Lines of communication for water purposes, between the polar caps, on the one hand, and the centres of population, on the other, would be the artificial markings we should expect to perceive.

Now, it is not a little startling that the semblance of just such signs of intelligent interference with nature is what we discern on the face of Mars, — in the canals and oases. So dominant in its mien is the pencil-like directness of the canals as to be the trait that primarily strikes an unprejudiced observer who beholds this astounding system of lines under favorable definition for the first time, and its impressiveness only grows on him with study of the phenomena. That they suggested rule and compass, Schiaparelli said of them long ago, without committing himself as to what they were. In perception the great observer was, as usual, quite right; and the better they are seen the more they justify the statement. Punctilious in their precision, they outdo in method all attempts of freehand drawing to copy them. Often has the writer tried to represent the regularity he saw, only to draw and redraw his lines in vain. Nothing short of ruling them could have

reproduced what the telescope revealed. Strange as their depiction may look in the drawings, the originals look stranger still. Indeed, that they should look unnatural when properly depicted is not unnatural if they are so in fact. For it is the geodetic precision which the lines exhibit that instantly stamps them to consciousness as artificial. The inference is so forthright as to be shared by those who have not seen them to the extent of instant denial of their objectivity. Drawings of them look too strange to be true. So scepticism imputes to the draughtsman their artificial fashioning, not realizing that by so doing it bears unconscious witness to their character. For in order to disprove the deduction it is driven to deny the fact. Now the fact can look after itself and will be recognized in time. For that the lines are as I have stated is beyond doubt. Each return of the planet shows them more and more geometric as sites are bettered and training improves.

Suggestive of design as their initial appearance is, the idea of artificiality receives further sanction from more careful consideration, even from a static point of view, on at least eight counts: —

1. Their straightness;
2. Their individually uniform size;
3. Their extreme tenuity;
4. The dual character of some of them;

5. Their position with regard to the planet's fundamental features;

6. Their relation to the oases;

7. The character of these spots; and, finally,

8. The systematic networking by both canals and spots of the whole surface of the planet.

Now, no natural phenomena within our knowledge show such regularity on such a scale upon any one of these eight counts, *a fortiori* upon all. When one considers that these lines run for thousands of miles in an unswerving direction, as far relatively as from London to Bombay, and as far actually as from Boston to San Francisco, the inadequacy of natural explanation becomes glaring.

These several counts become more expressive of design the farther one looks into them. Straightness upon a sphere means the following of an arc of a great circle. The lines, then, are arcs of great circles. Now, the great circle course is the shortest distance connecting two given points. The canals of Mars, then, practice this economy; they connect their terminals by the shortest, that is, other things equal, by the quickest and least wasteful path. Their preserving a uniform width throughout this distance is an equally unnatural feature for any natural action to exhibit, but a perfectly natural one for an unnatural agent. For means of communication for whatever cause would

probably be fashioned of like countenance throughout. Their extreme tenuity is a third trait pointing to artificiality; inasmuch as the narrower they are, the more probable is their construction by local intelligence. Even more inexplicable, except from intent, is their dual character. For them to parallel one another like the twin rails of a railway track, seems quite beyond the powers of natural causation. Enigmatic, indeed, from a natural standpoint, they cease to be so enigmatic viewed from an artificial one; and this the more by reason of what has lately been learnt of the character of their distribution. That they are found most plentifully near the equator, where the latitudinal girth is greatest, and thence diminish in numbers to about latitude 60°, where they disappear, — and this not relatively to the amount of surface but actually, — is very significant. It is quite incapable of natural explanation, and can only be accounted for on some theory of design such as lines of communication, or canals conducting water down the latitudes for distribution. So that this distribution of the doubles is in keeping with the law of development disclosed by the canals *en masse*. Channels and return-channels the two lines of the pair may be, but about this we can at present posit nothing. The relation may be of still greater complexity, and we must carefully distinguish between surmise and deduction.

The position of the canals, with regard to the main features of the disk, has a cogency of its own, an argument from time. The places from which the lines start and to which they go are such as to imply a dependence of the latter upon the former chronologically. The lines are logically superposed upon the natural features; not as if they had grown there, but as if they had been placed there for topographic cause. Those termini are used which we should ourselves select for stations of intercommunication. For the lines not only leave important geodetic points, but they travel directly to equally salient ones.

The connection of the canals with the oases is no less telltale of intent. The spots are found only at junctions, clearly the seal and sanction of such rendezvous. Their relation to the canals that enter them bespeaks method and design. Centring single lines, they are inclosed by doubles, a disposition such as would be true did they hold a pivotal position in the planet's economy.

The shape of the oases also suggests significance. Their form is round, a solid circle of shading of so deep a tone as to seem black, although undoubtedly in truth blue-green. Now, a circular area has this peculiar property, that it incloses for a given length of perimeter the maximum of space. Any other area has a longer inclosing boundary for the surface inclosed. Con-

sidering each area to be made up of onion-like envelops to an original core, each similar in shape to the kernel, we see that the property in question means that the average distance for points of the circular area from the centre is less than the same distance for those of any other figure. This has immediate bearing on the possible fashioning of such areas. For sufficient intelligence in the fashioners would certainly lead to a construction, where the greatest area could be attended to at the least expenditure of force. This would be where the distance to be traveled from the centre to all the desired points was on the average least; that is, the area would be round.

But last and all-embracing in its import is the system which the canals form. Instead of running at haphazard, the canals are interconnected in a most remarkable manner. They seek centres instead of avoiding them. The centres are linked thus perfectly one with another, an arrangement which could not result from centres, whether of explosion or otherwise, which were themselves discrete. Furthermore, the system covers the whole surface of the planet, dark areas and light ones alike, a world-wide distribution which exceeds the bounds of natural possibility. Any force which could act longitudinally on such a scale must be limited latitudinally in its action, as witness the belts of Jupiter or the spots upon the sun. Rotational, climatic, or

other physical cause could not fail of zonal expression. Yet these lines are grandly indifferent to such compelling influences. Finally, the system after meshing the surface in its entirety runs straight into the polar caps.

It is, then, a system whose end and aim is the tapping of the snow-cap for the water there semiannually let loose; then to distribute it over the planet's face.

Function of this very sort is evidenced by the look of the canals. Further study during the last eleven years as to their behavior leads to a like conclusion, while at the same time it goes much farther by revealing the action in the case. This action proves to be not only in accord with the theory, but interestingly explanatory of the process.

In the first place, the canals have shown themselves, as they showed to Schiaparelli, to be seasonal phenomena. This negatives afresh the possibility of their being cracks. But furthermore, their seasonal behavior turns out to follow a law quite different from what we know on earth and betokens that they are indebted to the melting of the polar cap for their annual growth, even more directly than to the sun, and that vegetation is the only thing that satisfactorily accounts for their conduct. But again this is not all. Their time of quickening proceeds with singular uniformity down the disk, not only to, but *across the equator*. Now, this last fact has peculiar significance.

So large are the planetary masses that no substance can resist the strains due to the cosmic forces acting on them to change their shape till it becomes one of stable equilibrium. Thus a body of planetary size, if unrotating, becomes a sphere except for solar tidal deformation; if rotating, it takes on a spheroidal form exactly expressive, as far as observation goes, of the so-called centrifugal force at work. Mars presents such a figure, being flattened out to correspond to its axial rotation. Its surface, therefore, is in fluid equilibrium, or, in other words, a particle of liquid at any point of its surface at the present time would stay where it was, devoid of inclination to move elsewhere.

Now, the water which quickens the verdure of the canals moves from the neighborhood of the pole down to the equator as the season advances. This it does, then, irrespective of gravity. No natural force propels it, and the inference is forthright and inevitable that it is artificially helped to its end. There seems to be no escape from this deduction. Water flows only downhill, and there is no such thing as downhill on a surface already in fluid equilibrium. A few canals might presumably be so situated that their flow could, by inequality of terrane, lie equatorward, but not all. As we see on the earth, rivers flow impartially to all points of the compass, dependent only upon unevenness of the local surface conditions. Now, it is not in particular

but by general consent that the canal system of Mars develops from pole to equator.

From the respective times at which the minima take place, it appears that the canal-quickening occupies fifty-two days, as evidenced by the successive vegetal darkenings to descend from latitude 72° north to latitude 0°, a journey of 2650 miles. This gives for the water a speed of fifty-one miles a day, or 2.1 miles an hour. The rate of progression is remarkably uniform; and this abets the deduction as to assisted transference. The simple fact that it is carried from near the pole to the equator is sufficiently telltale of extrinsic aid, but the uniformity of the action increases its significance.

But the fact is more unnatural yet. The growth pays no regard to the equator, but proceeds across it as if it did not exist into the planet's other hemisphere. Here is something still more telling than its travel to this point. For even if we suppose, for the sake of argument, that natural forces took the water down to the equator, their action must there be certainly reversed and the equator prove a dead-line to pass which were impossible.

CHAPTER XXXII

CONCLUSION

THAT Mars is inhabited by beings of some sort or other we may consider as certain as it is uncertain what those beings may be. The theory of the existence of intelligent life on Mars may be likened to the atomic theory in chemistry in that in both we are led to the belief in units which we are alike unable to define. Both theories explain the facts in their respective fields and are the only theories that do, while as to what an atom may resemble we know as little as what a Martian may be like. But the behavior of chemic compounds points to the existence of atoms too small for us to see, and in the same way the aspect and behavior of the Martian markings implies the action of agents too far away to be made out.

But though in neither case can we tell anything of the bodily form of its unit, we can in both predicate a good deal about their workings. Apart from the general fact of intelligence implied by the geometric character of their constructions, is the evidence as to its degree afforded by the cosmopolitan extent of the action. Girdling their globe and stretching from pole to pole, the Martian canal system not only embraces their

whole world, but is an organized entity. Each canal joins another, which in turn connects with a third, and so on over the entire surface of the planet. This continuity of construction posits a community of interest. Now, when we consider that though not so large as the Earth the world of Mars is one of 4200 miles diameter and therefore containing something like 55,000,000 of square miles, the unity of the process acquires considerable significance. The supposed vast enterprises of the earth look small beside it. None of them but become local in comparison, gigantic as they seem to us to be.

The first thing that is forced on us in conclusion is the necessarily intelligent and non-bellicose character of the community which could thus act as a unit throughout its globe. War is a survival among us from savage times and affects now chiefly the boyish and unthinking element of the nation. The wisest realize that there are better ways for practicing heroism and other and more certain ends of insuring the survival of the fittest. It is something a people outgrow. But whether they consciously practice peace or not, nature in its evolution eventually practices it for them, and after enough of the inhabitants of a globe have killed each other off, the remainder must find it more advantageous to work together for the common good. Whether increasing common sense or increasing necessity was the spur

that drove the Martians to this eminently sagacious state we cannot say, but it is certain that reached it they have, and equally certain that if they had not they must all die. When a planet has attained to the age of advancing decrepitude, and the remnant of its water supply resides simply in its polar caps, these can only be effectively tapped for the benefit of the inhabitants when arctic and equatorial peoples are at one. Difference of policy on the question of the all-important water supply means nothing short of death. Isolated communities cannot there be sufficient unto themselves; they must combine to solidarity or perish.

From the fact, therefore, that the reticulated canal system is an elaborate entity embracing the whole planet from one pole to the other, we have not only proof of the world-wide sagacity of its builders, but a very suggestive side-light, to the fact that only a universal necessity such as water could well be its underlying cause.

Possessed of important bearing upon the possibility of life on Mars is the rather recent appreciation that the habitat of both plants and animals is conditioned not by the minimum, nor by the mean temperature of the locality, but by the maximum heat attained in the region. Not only is the minimum thermometric point no determinator of a dead-line, but even a mean temperature does not measure organic capability. The reason for this is that the continuance of the species

seems to depend solely upon the possibility of reproduction, and this in turn upon a suitable temperature at the critical period of the plant's or animal's career. Contrary to previous ideas on the subject, Merriam found this to be the case with the fauna of the San Francisco Peak region in northern Arizona. The region was peculiarly fitted for a test, because of rising a boreal island of life out of a subtropic sea of desert. It thus reproduced along its flanks the conditions of climates farther north, altitude taking the part of latitude, one succeeding another until at the top stood the arctic zone. Merriam showed that the existence of life there was dependent solely upon a sufficiency of warmth at the breeding season. If that were enough the animal or plant propagated its kind, and held its foothold against adverse conditions during the rest of the year. This it did by living during its brief summer and then going into hibernation the balance of the time. Nature in short suspended its functions to a large extent for months together, enabling it to resurrect when the conditions turned.

Hibernation proves thus to be a trait acquired by the organism in consequence of climatic conditions. Like all such it can only be developed in time, since nature is incapable of abrupt transition. An animal suddenly transported from the tropic to a sub-arctic zone will

perish, because it has not yet learnt the trick of winter sleeping. While still characterized by seasonal insomnia it is incapable of storing its energies and biding its time. But given time enough to acquire the art, its existence is determined solely by the enjoyment of heat enough at some season to permit of the vital possibility of reproducing its kind.

Diurnal shutting off of the heat affects the process but little, provided the fall be not below freezing at the hottest season. So much is shown by the fauna of our arctic and sub-arctic zones, but still more pertinently to Mars by the zones of the San Francisco Peak region, since the thinner air of altitude, through which a greater amount of heat can radiate off, is there substituted for the thicker one of latitudinally equal isotherms. Here again with the diurnal as before with the seasonal it is the maximum, not the mean, or, till low, even the minimum temperature, that tells.

Now, with Mars the state of things is completely in accord with what is thus demanded for the existence of life. The Martian climate is one of extremes, where considerable heat treads on the heels of great cold. And the one of these two conditions is as certain as the other, as the condition of the planet's surface shows conclusively. In summer and during the day it must be decidedly hot, certainly well above any possible freezing, a thinner air blanket actually increasing the

amount of heat that reaches the surface, though affecting the length of time of its retention unfavorably. The maximum temperature, therefore, cannot be low. The minimum of course is; but as we have just seen, it is the maximum that regulates the possibility of life. In spite, therefore, of a winter probably longer and colder than our own, organic life is not in the least debarred from finding itself there.

Indeed, the conditions appear to be such as to put a premium upon life of a high order. The Martian year being twice as long as our own, the summer is there proportionately extended. Even in the southern hemisphere, the one where the summer is the shortest, it lasts for 158 days, while at the same latitudes our own is but 90 days. This lengthening of the period of reproduction cannot but have an elevating effect upon the organism akin to the prolongation of childhood pointed out by John Fiske as playing so important a part in the evolution of the highest animals. Day and night, on the other hand, alternate there with approximately the same speed as here, and except for what is due to a thinner air covering reproduce our own terrestrial diurnal conditions, which as we saw are not inimical to life.

In this respect, then, Mars proves to be by no means so bad a habitat. It offers another example of how increasing knowledge widens the domain that life may

occupy. Just as we have now found organic existence in abyssal depths of sea and in excessive degrees of both heat and cold, so do we find from exploration of our island mountains, which more than any other locality on earth facsimile the Martian surface, its possession there as well.

Another point, too, is worth consideration. In an aging world where the conditions of life have grown more difficult, mentality must characterize more and more its beings in order for them to survive, and would in consequence tend to be evolved. To find, therefore, upon Mars highly intelligent life is what the planet's state would lead one to expect.

To some people it may seem that the very strangeness of Martian life precludes for it an appeal to human interest. To me this is but a near-sighted view. The less the life there proves a counterpart of our earthly state of things, the more it fires fancy and piques inquiry as to what it be. We all have felt this impulse in our childhood as our ancestors did before us, when they conjured goblins and spirits from the vasty void, and if our energy continue we never cease to feel its force through life. We but exchange, as our years increase, the romance of fiction for the more thrilling romance of fact. As we grow older we demand reality, but so this requisite be fulfilled the stranger the realization the better we are pleased. Perhaps it is the more

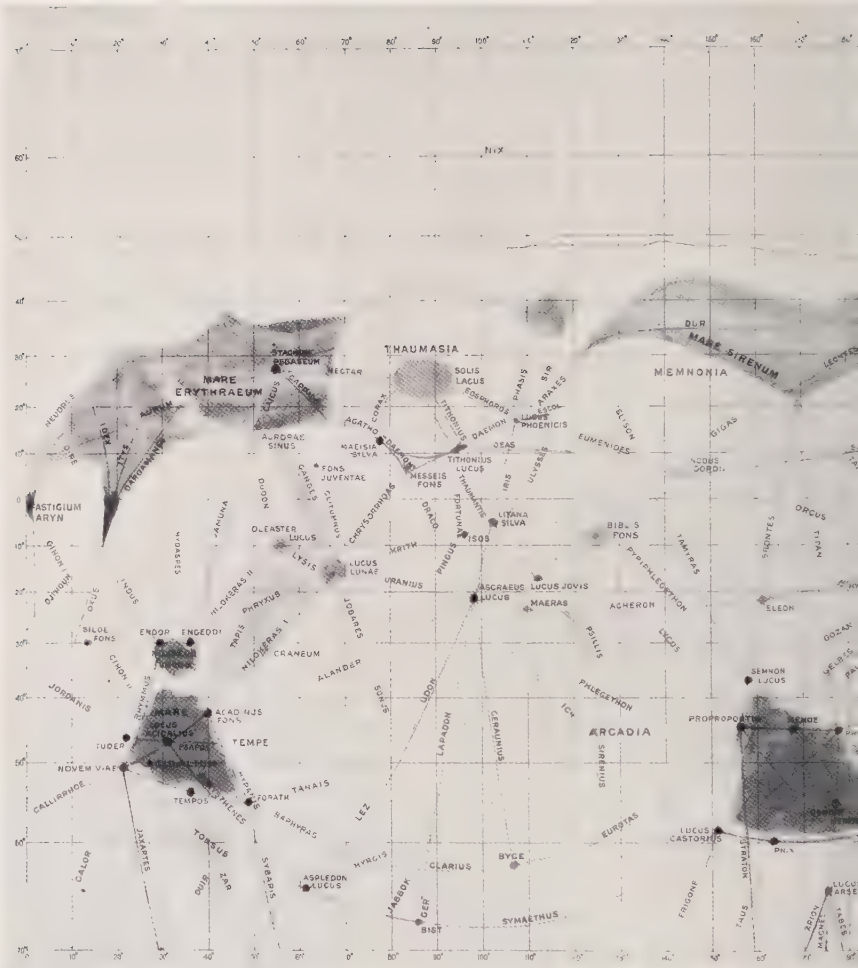
vivid imagination of youth that enables us all then to dispense with the hall-mark of actuality upon our cherished visions; perhaps a deeper sense of our own oneness with nature as we get on makes us insist upon getting the real thing. Whatever the reason be, certain it is that with the years a narration, no matter how enthralling, takes added hold of us for being true. But though we crave this solid foothold for our conceptions, we yield on that account no jot or tittle of our interest for the unexpected.

Good reason we have for the allurement we feel toward what is least like us. For the wider the separation from the familiar, the greater the parallax the new affords for cosmic comprehension. That which differs little yields little to the knowledge already possessed. Just as a longer base line gives us a better measure of the distance of the sun, so here the more diverse the aspects, the farther back they push the common starting-point and furnish proportionately comprehensive insight into the course by which each came to be what it is. By studying others we learn about ourselves, and though from the remote we learn less easily, we eventually learn the more. Even on the side, then, that touches most men, the personal, the strangeness of the subject should to the far-seeing prove all the greater magnet.

One of the things that makes Mars of such transcen-

dent interest to man is the foresight it affords of the course earthly evolution is to pursue. On our own world we are able only to study our present and our past; in Mars we are able to glimpse, in some sort, our future. Different as the course of life on the two planets undoubtedly has been, the one helps, however imperfectly, to better understanding of the other.

Another, more abstract but no less alluring, appeals to that desire innate in man to know about the cosmos of which he forms a part and which we call by the name of science. Study of Mars responds to this craving both directly by revelation of the secrets of another world and indirectly by the bearing of what we thus learn upon our understanding of the laws of the universe. For the facts thus acquired broaden our conceptions in every branch of science. Some day our own geology, meteorology, and the rest will stand indebted to study of the planet Mars for advance along their respective lines. Already the most alert of those professing them are lending ear to information from this source, and such cosmopolitanism can but increase as the years roll on. Today what we already know is helping to comprehension of another world; in a not distant future we shall be repaid with interest, and what that other world shall have taught us will redound to a better knowledge of our own, and of that cosmos of which the two form part.



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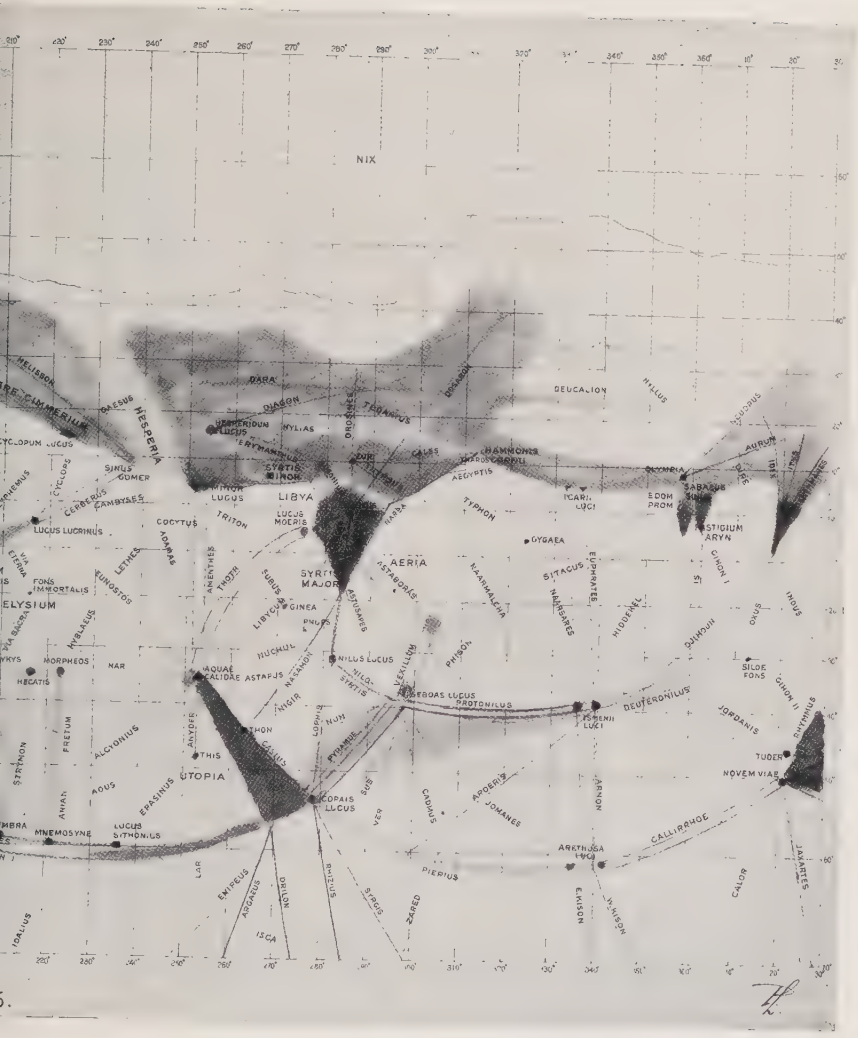
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ASTAPUS
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NILUS LUCUS
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SEBOAS LUCUS
PROTONILUS
DEUTERONILUS
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SILOE FONS
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By PERCIVAL LOWELL

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